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Experimental Analysis of Axially Loaded Aerated Mortar Filled Tubes

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Abstract - **This study present, an experimental work on axially loaded aerated mortar filled steel tube in axial compression. The main objective is that to determine maximum load carrying capacity of aerated mortar filled steel tubes and detailed study on the behavior of steel tubes. From the experimental investigation, it was concluded that an empty tube shows concertina mode of failure where as in normal mortar Euler buckling mode failure was observed. It is concluded that Energy absorbing capacity of steel tubes is increased by filling the tubes with aerated/normal mortar and the order of increase is about 64% when filled with aerated mortar and as high as 176% when filled with normal mortar.**
Keywords: **Aerated mortar filled steel tube, Buckling mode, Yield strength and Energy absorption capacity, Compressive strength, Compression test.**

I.INTRODUCTION

Aerated concrete is also known as autoclaved concrete, porous concrete and light weight concrete. The material was invented in mid 1920s by the Swedish architect and inventor Dr. Johan Axel Erikson.

Aerated concrete is a mixture of cement, fine aggregate and water and aluminium powder. It does not contain coarse aggregate. The aerated concrete is used for various engineering works like Light weight fill, pipe filling, backfill grouting, cavity filling etc. ACFT column have many advantages compared to the conventional R.C.C. columns. They reduces the use of formwork, in fact steel encasing it acts as its formwork during construction. Various innovative ideas have been implemented regarding the shape of Steel tube encasing due to its flexibility in the moulding. Zhong Tao [2] used stiffeners in CFT columns and found that, on increasing the stiffener number,the compressive strength of CFT column also increased.Concrete core in the concrete filled steel tube columns prevents buckling in in-ward direction and the steel tube provides confinement Effects for loaded columns. The increment in axial strength in CFT columns increases as the thickness of the steel tube is increased and when the grade of concrete is reduced. Burak Evirgen [9] used different shaped steel tubes and concluded round shaped steel tubes showed

higher ductility. In this research axially loaded aerated mortar filled steel tubes on circular section (ACFT) will be carried out. Nine specimen with outer diameter to thickness ratio 25.33 and length to diameter ratio 3 were tested and failure pattern obtained are presented.

II.LITERATURE REVIEW

C.N. Srinivasan focussed on the fundamental questions that influence the behavior of concrete filled steel tubes.

A summary of the results of studies on the following aspects carried out by the discusser (Srinivasan 1985, 1991) are reported in this discussion:

1. Confining action in circular and square in-filled circular tubes (ICT).
2. Triaxial effects on the core and biaxial effects on the shell.
3. The presence of lateral strain compatibility and complete interaction of the core and the shell, over the entire range of loading.
4. The effect of loading method and a study of connections.
5. The factors governing the service and the ultimate load behavior.
6. The effect of wall thickness, diameter, and concrete mix.

The test program was as follows:

a. 150 mm diameter in-filled circular and square tubes of 300–1,200 mm lengths were tested to develop a stress strain relationship for the core and the shell and to study items 1–3 above.
b. A comparative study of samples where the bond between the core and the shell has been broken,

and where no such steps have been taken, was studied. After the tests, the samples were split longitudinally to study the concrete face, and it was found that the concrete core retained its integrity. The validity of the proposed load-strain relationship.

c. In-filled circular tubes (ICT) 1,200 mm, 1,840 mm, and 2,500 mm long were tested for both axial (12 specimens) and eccentric loaded conditions (13 specimens). In 8 specimens, the connection details and transfer of load from horizontal (beams and slabs) to vertical members (CITC) were also studied.
d. In addition, eight specimens were tested to study the presence of bond at the concrete-steel interface. Six specimens were tested to study the effect of the lateral load enhancement factor with the slenderness ratio.

Amir Fam1 et al investigated an experimental work and analytical modeling for concrete-filled steel tubes (CFST) subjected to concentric axial compression and combined axial compression and lateral cyclic loading. The objective of the study is to evaluate the strength and ductility of CFST short columns and beam-column members under different bond and end loading conditions. Both bonded and unbounded specimens were tested, including application of the axial load to the composite steel-concrete section and to the concrete core only. Research findings indicate that the bond and end loading conditions did not affect the flexural strength of beam-column members significantly. On the other hand, the axial strengths of the unbounded short columns were slightly increased, compared to those of the bonded ones, while the stiffness of the unbounded specimens was slightly reduced. Test results were compared with the available design specifications, which were found to be conservative. The paper also presents an analytical model capable of predicting the flexural and axial load strength of CFST members. Experimental results were found to be in good agreement with the predicted values.

Shosuke Morino et al studied a concrete-filled steel tubes (CFT) column system has many advantages compared with ordinary steel or reinforced concrete system. One of the main advantages is the interaction between steel tube and concrete: occurrence of local buckling of steel tube is delayed by the restraint of concrete, and the strength of concrete is increased by the confining effect provided from the steel tube. Extensive research work has been done in Japan over the last 15 years, including “New Urban Housing Project” and “US-Japan Cooperative Earthquake Research Program”, in addition to the work done by individual universities and industries, which has been presented at the annual meeting of Architectural Institute of Japan (AIJ). This paper introduces the merits, design provisions and recent construction trends of CFT column systems in Japan, and discusses the results of trial designs of CFT theme structures which have been carried out to look for the advantages in the performance and construction cost compared with other constructional system.

III.MATERIALS

In this research work, cement, sand, aluminium powder, water and steel tubes were used and discussed below.

1. Cement: Ordinary Portland cement was used in this experimentation confirming to I.S. 12269:1987.
2. Sand: Locally available sand, zone I with specific gravity 2.74, confirming to I.S.383:1970
3. Water: Normal water
4. Aluminium powder used.
5. Steel tube: Steel tube having 276mm length, 76mm external diameter and 3mm thickness

Fig.1 shows the aluminium powder used in the experiment.

Fig.1 Aluminium powder

Table 1 represents the mix proportion required for preparing the mixture of concrete.

TABLE 1 MIX PROPORTION FOR M30 GRADE CONCRETE.

Material	Quantity (kg/m$^{3)}$	Ratio
Cement	437	1
Water	140	0.45
Fine aggregate	709	1.62
Coarse aggregate	1103	2.5

1.1 Mixing and Casting

For compressive strength, specimen of dimension 276mm length, 76mm external diameter and 3mm thickness were cast and demoulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 7 days.

1.2 *Aerated Mortar Specimens*

To investigate the effect of aluminium powder on ultimate compressive strength of aerated mortar, test specimen in the mix proportions of 1:3 (Cement,:Sand) with 0%,0.02%, 0.04%, 0.06%, 0.08%, 0.10%, 0.12%, 0.14%, 0.16% of aluminium powder by weight of cement and sand were cast by using a w/c ratio of 0.45.

Nine number of test specimens were used .Specimen for each percentage of alumina powder cited- were cast. For casting the specimens, weight batching, hand mixing and hand compaction were adopted. Cement and sand along with various percentage of aluminium powder were mixed in dry state till uniform colour was obtained. To this dry mixture, water was added slowly and mixed thoroughly. The weight mixture so obtained for all the categories of aluminium powder (except for 0% category) was placed in the standard steel moulds of 76mm cube size up to ¾th of their heights

(While the mixture was placed up to the top of the moulds for 0% aluminium powder category).

IV.EXPERIMENTAL INVESTIGATION

Compression Strength test

For compressive strength test, cube specimen of dimension 276mm length and 76mm external diameter and 3mm thickness were cast for M30grade of concrete. The moulds were filled with aerated concrete. After 24 hours, the specimens were demoulded and were transferred to curing tank wherein they were allowed to cure for 7 days. These specimens were tested in compression testing machine. The load was applied on tubes were tested and their value are calculated.
Compressive strength =Failure load/Area (MPa)
Fig.2 shows the specimens tested on the compression testing
machine.

Fig.2 Compression testing machine

V. RESULTS

Table 2 gives the result obtained during testing. At optimum Moisture Content, aluminium powder is added to get maximum compressive strength of aerated mortar in the mix proportion 1:3with w/c ratio 0.45 is 2% by weight of cement and sand.
Fig.3 shows the stress-strain relations

TABLE II RESULTS OF COMPRESSION TEST USING CYLINDER

Specimen no.	% age of Aluminium powder	Aluminium Powder (gm.)	Max. Force cal. At entire area (KN)	Max. Stress cal. At entire area (N/mm^2)	Max. Strain cal. At entire area (%)
1	0	0.00	274	15.5	4.51258
2	2	28.4	348	19.7	6.9110
3	4	56.8	259	14.7	8.788
4	6	85.2	264	14.9	5.1715
5	8	113.6	223	12.6	32.9830
6	10	142.0	334	18.9	5.8198
7	12	170.4	287	16.2	14.67
8	14	198.8	333	18.8	17.72
9	16	227.0	270	15.3	7.960

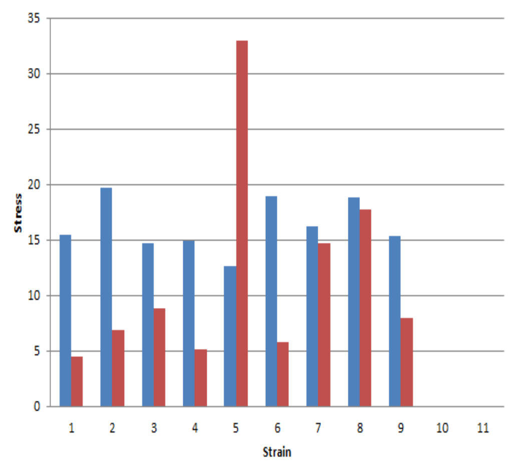


Fig. 3 Stress–Strain relations

VI. DISCUSSION OF FAILURE MODE

The steel tube specimens before and after testing, both in empty and mortar-filled conditions. Fig.5 shows the failure of hollow steel tube after testing a specimen on U.T.M.

Fig.6 shows the failure of normal mortar steel tube after testing a specimen on U.T.M. Fig.7 shows the failure of aerated mortar filled steel tubes after testing a specimen on U.T.M.

Fig.5 Hollow steel tube after failure on U.T.M.

Fig.5 shows that empty tubes have equal inward-outward buckling failure at one end known as concertina mode of failure.

Fig. 6 Failure of normal mortal Steel tube

Fig.6 shows the tubes with normal mortar eventually have Euler buckling mode failure. This is because in the early stages of loading, The poisons ratio for the mortar is lower than that of the steel. Thus the steel tubes have no confining effect on the mortar core.

Fig 7 Failure of Aerated mortar

Fig.7 shows the failure of aerated mortar, In this case of tubes filled with the aerated mortar, the failure mechanism is different. It undergoes equal and unequal inward-outward buckling at initial and final stages of loading .This happen due to presence of cellular structure in the aerated mortar. At the initial stages of loading, the aerated mortar first undergoes compaction instead of offering resistance to the applied load. As a result, delay occurs in the formation of the radial pressure at the steel-mortar interface. Hence, equal inward-outward buckling failure occurs at both the ends of the tube simultaneously. As a consequence, the tube length reduces approximately to half of its original value. As the load increases, the compaction process continues and at one stage, full compaction is achieved. On further loading, the radial pressure gradually increases which prevents the inward buckling of the steel tubes. Owing to this result, unequal inward-outward buckling failure takes place for the remaining length of the tubes. At the final stages of loading, the radial pressure at the interface and hence hoop tension in the steel tubes is much greater. Because of high hoop tension, out of three tubes of its kind tested, one of the steel tubes had a split failure at vertical joint of the tube. This indicates that the steel tubes filled with the aerated mortar fails by undergoing folding type mechanism failure in the horizontal plane.

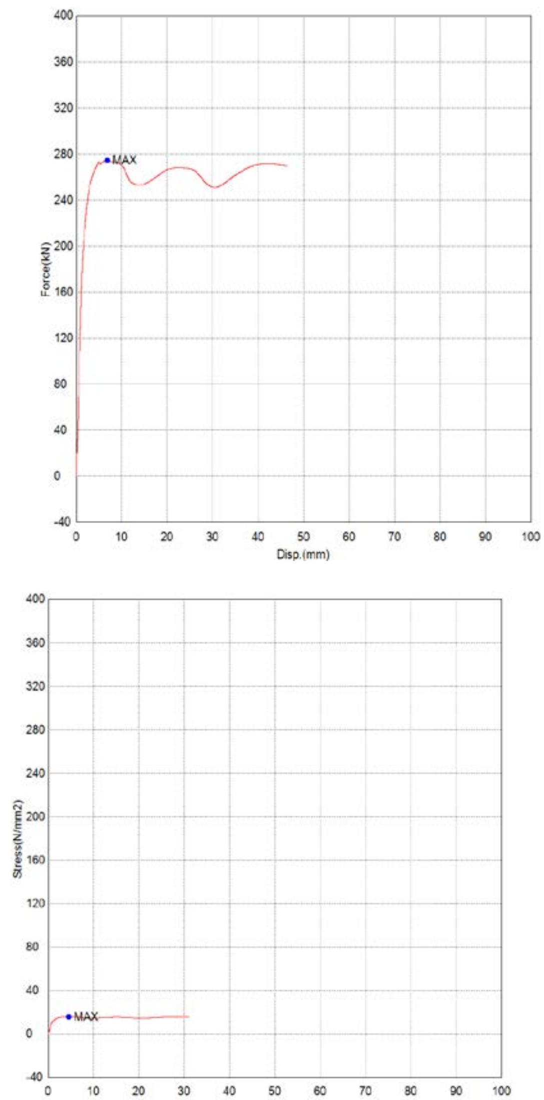


Fig. 8 Force vs displacement and stress vs strain curve For 0% mortar

From the Fig-8, the maximum peak load is 274KN and the maximum stress is 15.5N/mm^2

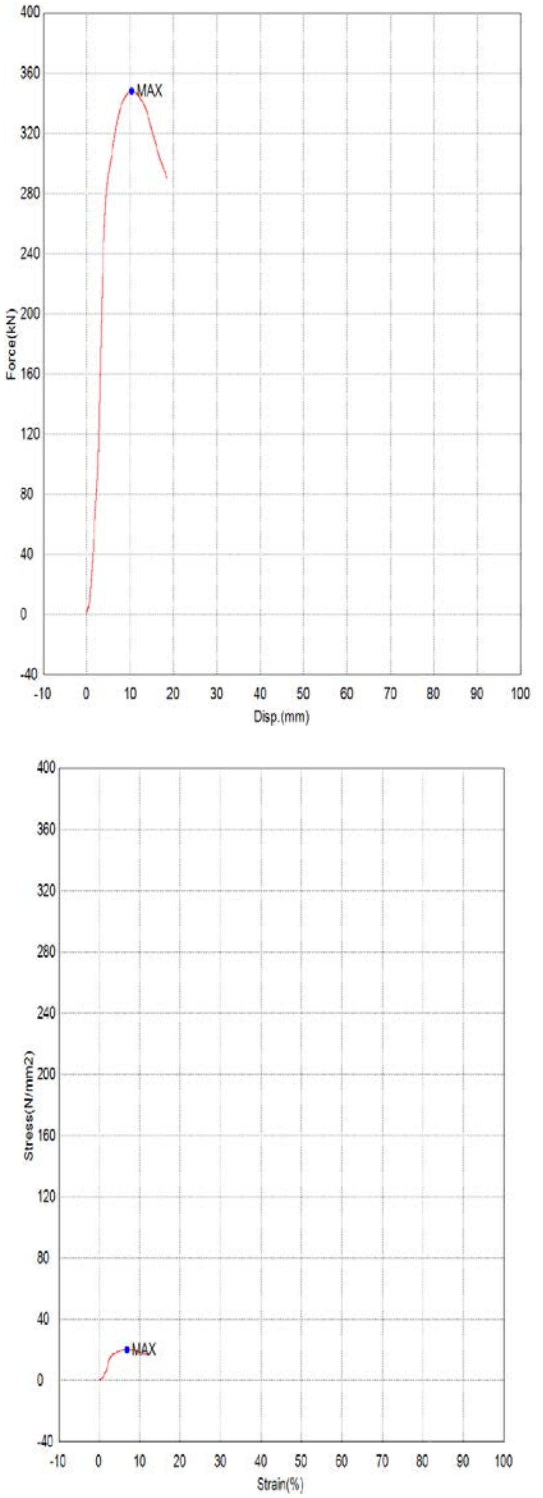


Fig. 9 Force vs displacement and stress vs strain curve
For 2% mortar

From the Fig.9. the maximum peak load is348KN and the maximum stress is 19.7N/mm^2

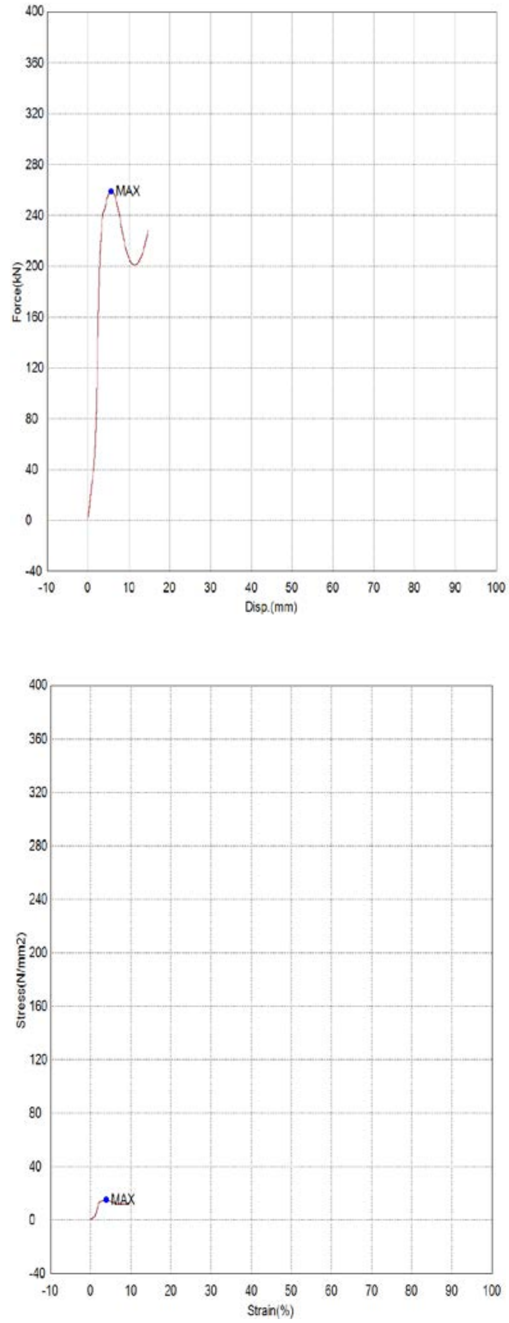


Fig. 10 Force vs displacement and stress vs strain curve
For 4% mortar

From the Fig.10. the maximum peak load is 259KN and the maximum stress is 14.7N/mm^2

Fig.8-16 shows the force vs displacement and stress vs strain curves. Failure mechanisms of circular steel tubes both in empty and mortar filled conditions are different and the tubes have folding type failure when filled with aerated mortar and buckling type failure when filled with normal mortar.

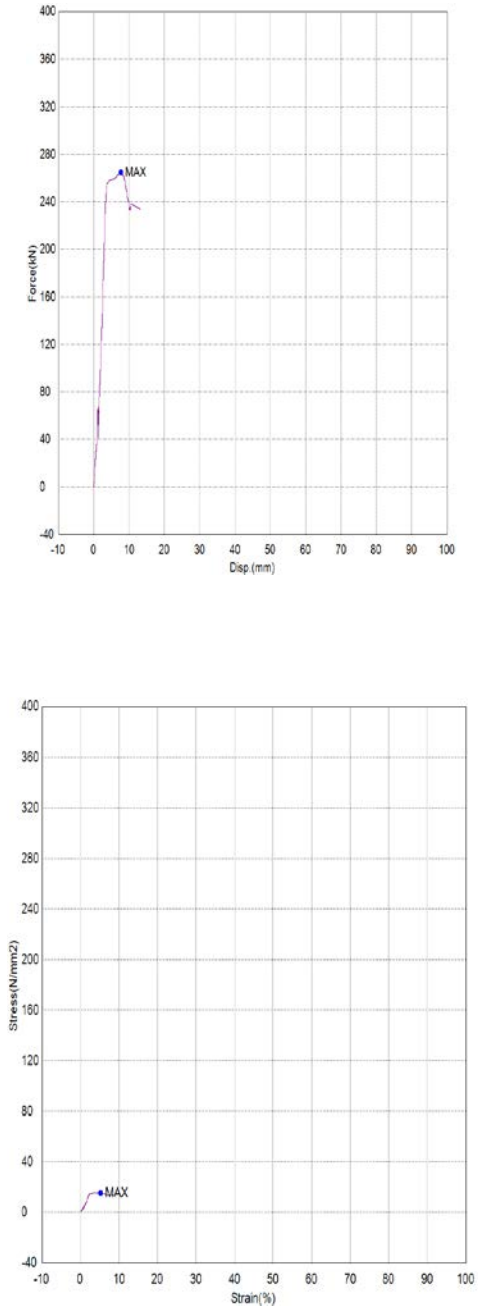


Fig. 11 Force vs displacement and stress vs strain curve
For 6% mortar

From the Fig.11 the maximum peak load is 264KN and the maximum stress is 14.9N/mm^2

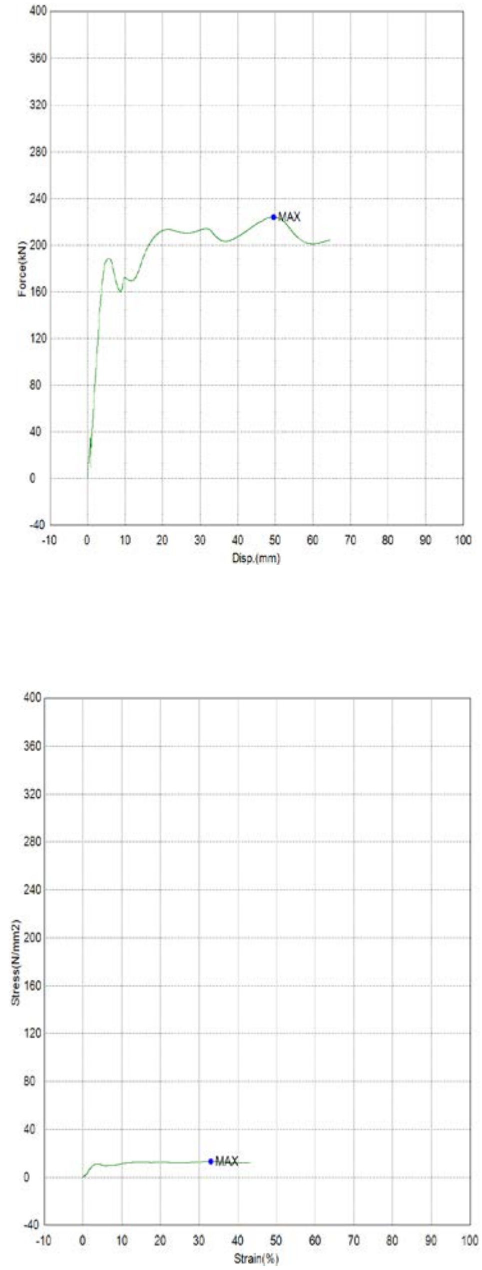


Fig. 12 Force displacement and stress strain curve
For 8% mortar

From the Fig.12 the maximum peak load is 223KN and the maximum stress is 12.6N/mm^2

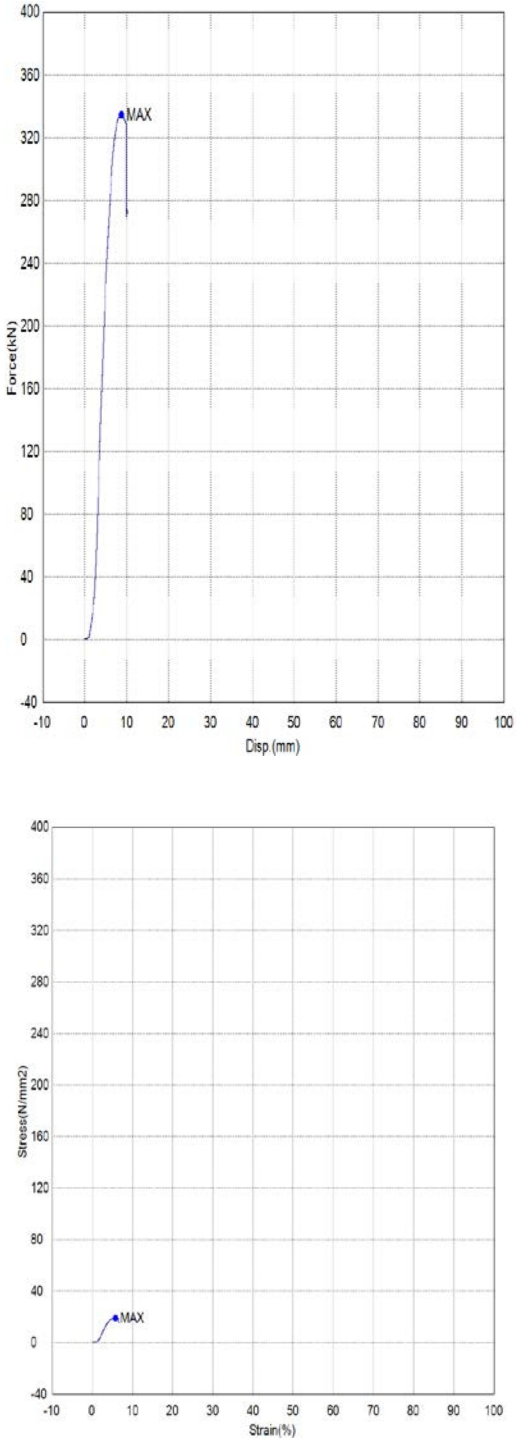


Fig. 13 Force displacement and stress strain curve For 10% mortar

From the Fig.13. the maximum peak load is34KN and the maximum stress is 18.9N/mm^2

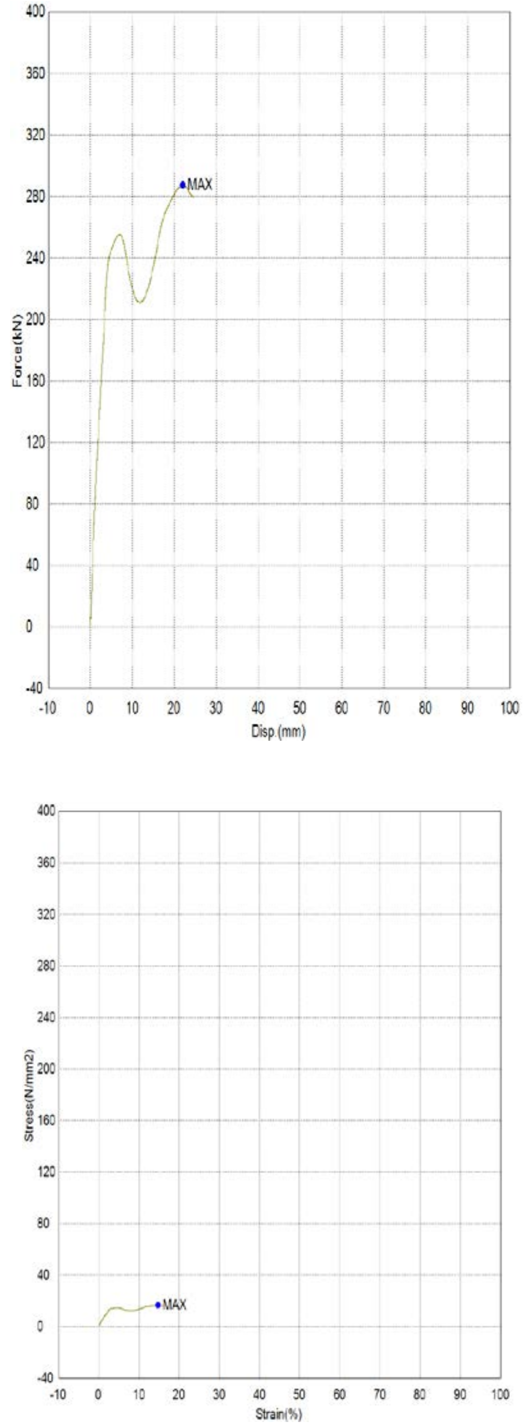


Fig. 14 Force displacement and stress strain curve For 12% mortar

From the Fig.14. the maximum peak load is287KN and maximum stress is 16.2N/mm^2

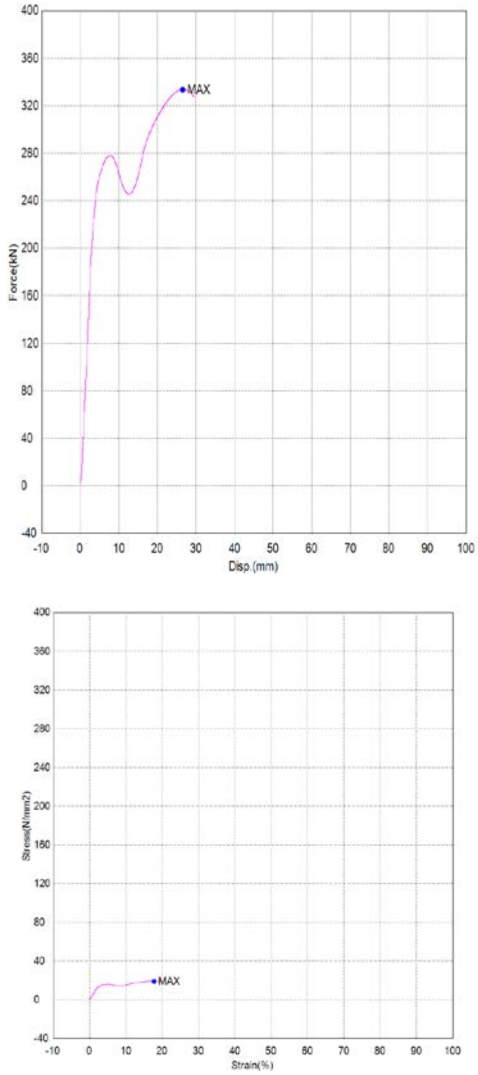
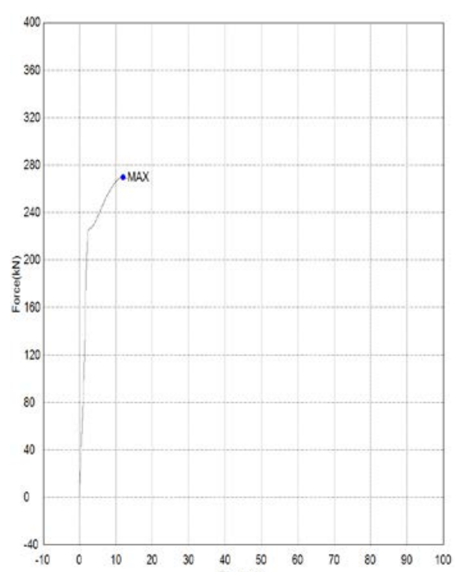


Fig. 15 Force displacement and stress strain curve For 14% mortar

From the Fig.15 the maximum peak load is 333KN and the maximum stress is18.8N/mm^2



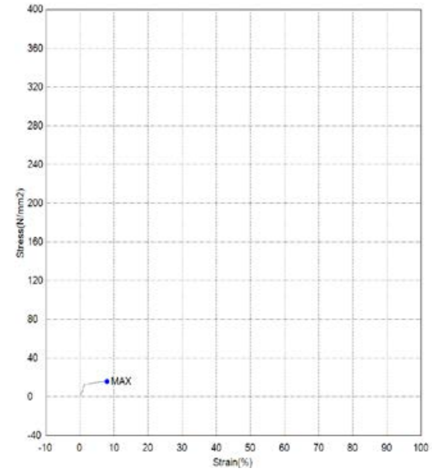


Fig. 16 Force displacement and stress strain curve For 16% mortar

From the Fig.16. the maximum peak load is 270KN and the maximum stress is 15.3N/mm^2

VII.CONCLUSION

1. Optimum content of aluminium powder is to be added to get maximum compressive strength of aerated mortar in the mix proportion of 1:3 with water-cement ratio of 0.40% and 0.02 % by weight of cement and sand.
2. Short, circular mild steel tubes with $D_0/t = 25.33$ and $L/D_0 = 3$, when filled with aerated and normal mortars have yield strengths of about 5 % and 38 %, higher than that of empty tubes.
3. Stiffness of hollow circular mild steel tubes reduces when they are filled with mortar and the order of reduction is about 73.6 % when filled with normal mortar and only 7 % when filled with aerated mortar.
4. Energy absorbing capacity of steel tubes is increased by filling the tubes with aerated/normal mortar and the order of increase is about 64 % when filled with aerated mortar and as high as 176 % when filled with normal mortar.
5. Failure mechanisms of circular steel tubes both in empty and mortar filled conditions are different and the tubes have folding type failure when filled with aerated mortar and buckling type failure when filled with normal mortar.
6. Steel-mortar composite tubes have many favorable characteristics like higher yield strength, more energy absorbing capacity, etc. when compared with empty tubes. Hence, they can be used for the construction of buildings, bridges, offshore structures, etc. at the seismic prone areas where these characteristics are inevitable for serviceability of structures. Also, in these structures wherever buckling type failure is undesirable, tubes filled with lightweight aerated mortar/concrete can be used and this will reduce the inertial force setup during an earthquake.

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