Observations on the Behaviour of Seamed Steel Mortar Tubes

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ABSTRACT

This paper reports results taken from a wider investigation of the effect of various parameters on the fragmentation behaviour of steel firework mortar tubes. During simulated misfire experimental information was obtained relating to the role of the weld in determining rupture behaviour in seamed steel mortar tubes. The results have helped to resolve different opinions on the hazard posed by fragmentation of welded and seamless mortar tubes.

Keywords: mortar, fireworks, steel tube, seamed tube

Introduction

Accidents involving misfires in mortar tubes have been reported for over 100 years.[1] Generally, the shell fails to leave the mortar prior to the burst charge operating, and potentially lethal fragments are projected over a large area when the mortar tube shatters.

After an accident in 1988, at the Glasgow Garden Festival as a result of which a firework operator lost a leg,[2] the UK Health and Safety Executive examined the extent of current knowledge relating to the safe use of mortar tubes. Little published material was available at that time and therefore a programme of research was initiated to provide information on the fragmentation characteristics of different mortars tube types and the effectiveness of mitigation measures such as mortar tube burial and sandbagging. The need for such work was reinforced by subsequent accidents in Japan[2] during 1989 and two reports of prematurely exploding shells from the USA[3] in 1994. It is envisaged that safety-related information of this type could form an important input to the development of Guidance for firework display operators.

A recent survey of factors relating to the use of mortars at firework displays[4] provided information on the types of shells and mortar tubes commonly used in the UK. This enabled an experimental programme to be designed to investigate the fragmentation behaviour of a range of steel tubes when various types of firework shells were exploded in them.

It has been previously reported[2] that there are conflicting views in the literature on the suitability of seamless steel tubes for use as firework mortar tubes. The NFPA code[5] states that either seamed or seamless tubes are suitable, while Shimizu[6] suggests that seamless mortar tubes are unsafe because when they burst the fragments radiate in all directions. Shimizu recommends the use of welded tubes because he feels that they will fail preferentially at the weld and therefore the fragment danger area can be predicted. The Canada Centre for Mineral and Energy Technology (CANMET) has recently carried out a wide ranging study of firework mortar materials,[7] which included sheet steel spot-welded tubes. Their work considers the fragmentation of mortar tubes but does not discuss the position of tube failure in relation to the tube seam. A comparison of seamed and seamless tubes was therefore carried out as part of our wider study in order to resolve the differences between the published advice.

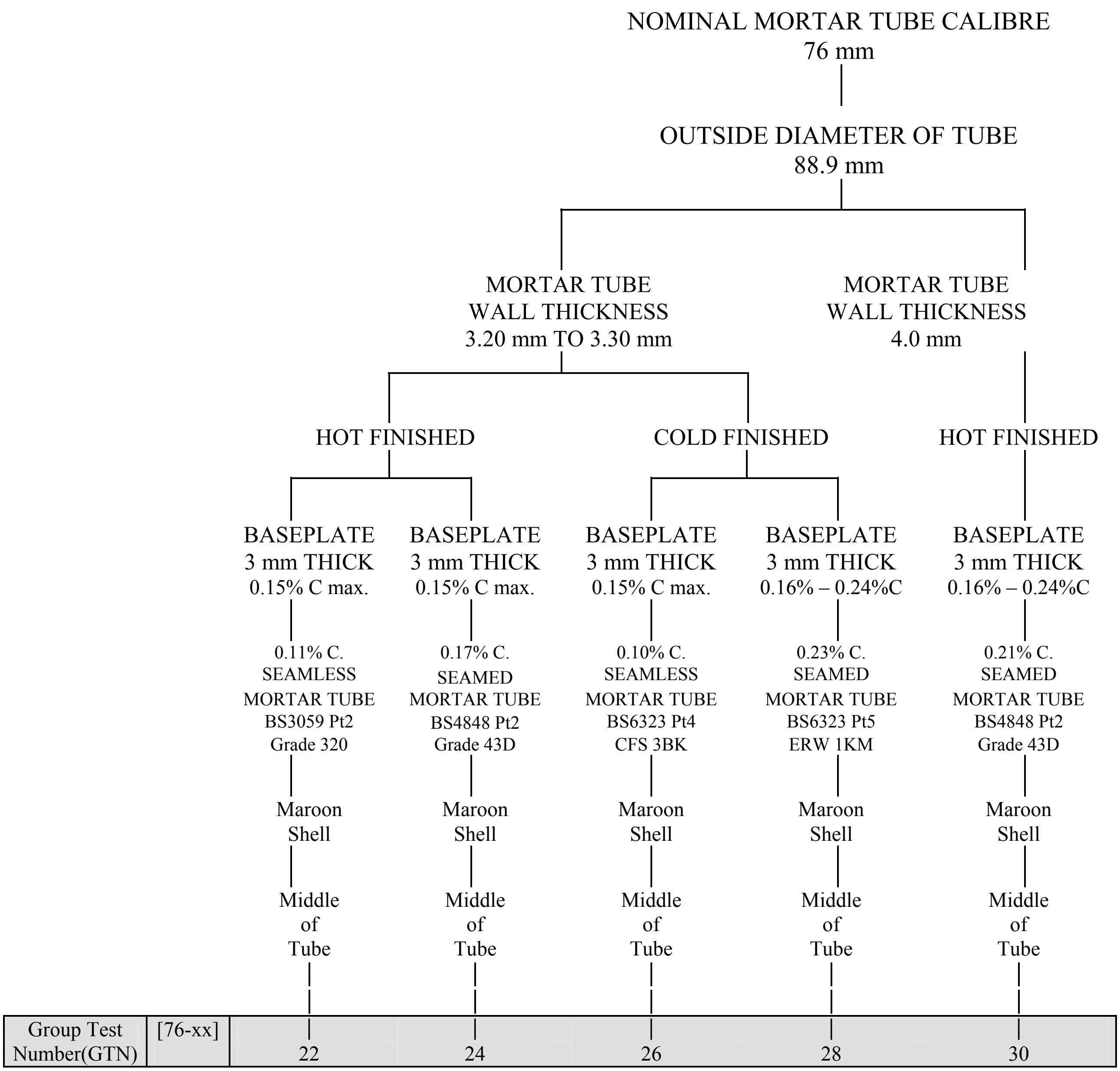
Experimental

Details of the mortar tubes used to provide data for this paper are given in Figures 1a and 1b. The variables shown in the Figures (percent carbon, wall thickness, type of finish, etc.) were chosen for the detailed study. A discussion of the reasons for their selection will be given in the full paper.[8]

The weld along the seamed tubes was formed using an electric resistance welding method. Baseplates for the 76 mm and 152 mm calibre tubes were 3 mm and 6 mm thick, respectively, and were fitted inside the tube wall and continuously welded into place using a Metal Inert Gas (MIG) welding technique.

Maroon shells for 76 mm and 152 mm calibre tubes and cylindrical multibreak shells for 152 mm calibre tubes were used because previous work[4] had identified that these types of shell were considered to pose the greatest fragmentation hazard.

Each group of tests in the full study was allocated a Group Test Number (GTN), these have



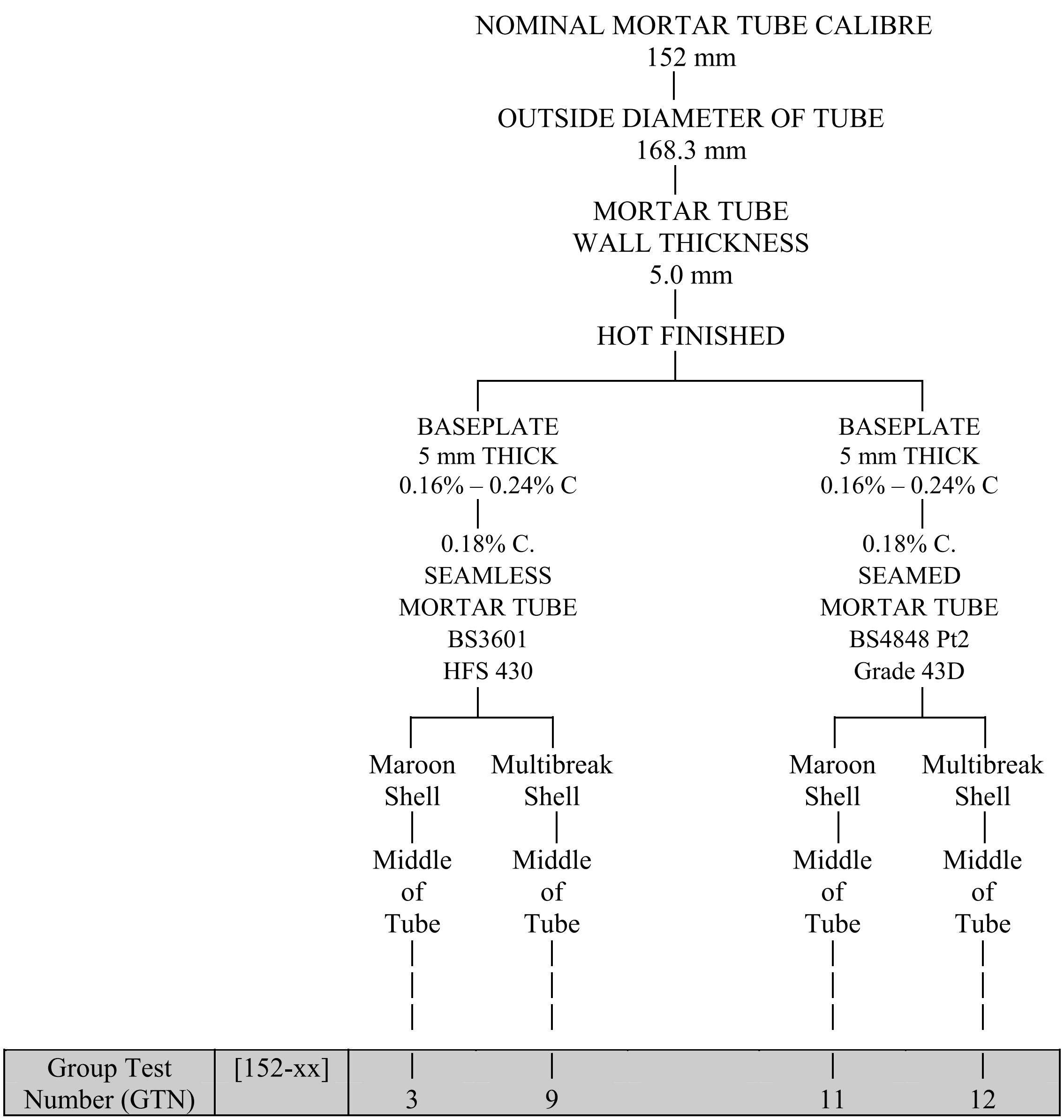
Mortar tube 600 mm long [exceeds NFPA min. of 21" (533 mm)]

Figure 1a. Firing programme for seamed and seamless mortar tubes.

been retained in this paper and are included in Figures 1a and 1b. A minimum of three tests was carried out on all the Group Test Numbers shown.

Experiments were carried out in a Blast Cell, 4 m square and 3.6 m high, which had a polyethylene sheet pinned over the thick wooden wall lining. Tests were done with the mortars positioned in the centre of the Blast Cell and seamed tubes placed so that the seam faced in the same direction each time.

During the course of the full study,[8] it was demonstrated that the lift charge made no measurable difference to the number of fragments produced in steel mortar tubes. Therefore, shells were fired with their lift charges removed. This allowed the shells to be suspended from insulated copper wire slings so that the half height of the shell was aligned with the half height of the mortar tube. The wire was taped to the shell, hooked over the top of the mortar tube and taped into position. Wire 0.56 mm in diameter was used for all except the 152 mm calibre mul-



Mortar tubes 1000 mm long [exceeds NFPA min. of 37" (940 mm)]

Figure 1b. Firing programme for seamed and seamless mortar tubes.

tibreak shells which, because of their larger mass, required wire of 1.25 mm diameter.

Tubes of 152 mm calibre were free standing, whereas the 76 mm calibre tubes were supported by inserting the tube base into a sheet of expanded polystyrene 50 mm thick and 450 mm square. It was considered that the constraint of the support would be insufficient to affect the fragmentation of the tube.

For each group of tests the x, y and z co-ordinates were recorded for fragments embedded in the wooden Cell lining, and for 'witness marks' made on the polyethylene sheet by deflected projectiles. A 'witness mark' was defined as a mark or cut on the plastic sheeting caused by a projectile that had not embedded into the wooden Cell lining at that point. The x, y co-ordinates described the plane of the floor, and the z co-ordinate the vertical displacement. Specific information about the trajectory of a particular fragment could not be inferred from the witness mark data but it was considered useful as a separate measure of the overall distribution of projectiles when a mortar tube burst. The distribution of fragments and witness marks on each wall of the Cell was examined in order to determine whether the fragments/witness marks had any directional characteristics.

Results

All the 76 mm calibre seamed and seamless mortar tubes that were tested ruptured when using maroon shells, while the tests with 152 mm seamed tubes showed that some tubes ruptured and others were only deformed. Table 1 indicates that some tubes failed along the welded seam while others did not. A total of nine 76 mm calibre seamed tubes were examined and it was found that four failed away from the seam. In the seven tests carried out on seamed 152 mm calibre tubes only two tubes ruptured, one along the seam and the other away from the seam (see Table 1).

No fragments were found embedded in the wooden Cell lining after any of the tests. The mean number of witness marks produced by 76 mm calibre, 3.25 mm wall thickness, seamed and seamless tubes was 6.5 and 12.5, respectively, while the equivalent value for the seamed 4 mm wall thickness tube was 6.0. In all tests the witness marks appeared to be randomly distributed on the walls of the Cell.

Table 1. Failure Details for Seamed Tubes.

Test Number	Group Test Number (GTN)	Calibre (mm)	Wall Thickness (mm)	Shell Type	Ruptured Along the Seam? (Y/N)
94/09/20/MA/04 94/09/20/MA/05 94/09/20/MA/06	76-24	76	3.25	Maroon	Y Y Y
94/09/29/MA/04 94/09/29/MA/05 94/09/29/MA/06	76-28	76	3.25	Maroon	Y N N
94/09/29/MA/07 94/09/29/MA/08 94/09/29/MA/09	76-30	76	4	Maroon	Y N N
94/10/06/MA/01 94/10/10/MA/01 94/10/10/MA/02	152-11	152	5	Maroon	Y Did not rupture Did not rupture
94/12/05/MU/10 94/12/05/MU/11 94/12/12/MU/01 94/10/20/MU/03	152-12	152	5	Cylindrical multibreak	Did not rupture Did not rupture Did not rupture N

Discussion

There is clear evidence from the study to indicate that the mode of failure of seamed tubes is not always consistent. Four of the nine 76 mm calibre tubes that failed had split away from the weld, while one out of two of the 152 mm calibre tubes that failed split away from the weld. The random distribution of the witness marks from the tests suggests that failure of seamed tubes does not occur preferentially at any one position on the tube. This work indicates that the technical basis from which safety procedures require specific positioning of the mortar seam may need to be examined in detail.

Some explanation of the above observations can be made by considering the purpose for which the tubes were originally manufactured. In the UK, mortar tubes are commonly made from commercially available steel tube used for general engineering purposes, where reproducible strength is required throughout the tube's length and circumference. Accordingly, when seamed tube is made, the manufacturers produce welded seams of comparable strength to the steel in the main body of the tube. This means that the seamed tubes should perform as well as the equivalent seamless tube and that the position at which the rupture originates cannot be predicted with any degree of certainty.

As the sheet steel tubes used in the CANMET study[7] were spot welded, the weld could be the weakest point in the tube, which would therefore be expected to fail at the seam. With tubes of this type it is possible that fragment trajectories may be predicted, but further work would be necessary to confirm this.

The mean number of witness marks observed for seamed tubes was approximately half that recorded for seamless tubes. This suggests that the number of projectiles produced from seamed tubes is less than that of equivalent seamless tubes, which may be a significant factor when considering the safety of such tubes. However, the number of witness marks does not directly measure the number of tube fragments produced because projectiles can be produced from the shell as well as the tube, and ricochets may also occur. In view of this and the small sample population, no firm conclusion can be drawn from these data until more extensive studies are undertaken.

Conclusions

This paper has considered the failure mode of firework mortar tubes fabricated from commercially available mild steel seamed and seamless tube. The work indicates that the trajectory of projectiles from a rupturing mortar cannot be predicted for either type of tube tested and that, in the light of these findings, safety procedures that assume a preferential direction for the fragmentation of seamed tubes may need to be examined.

References

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