CONCRETE MASONRY BUILDINGS IN NEW ZEALAND

by

I.L. Holmes*

ABSTRACT

Concrete masonry has developed rapidly in New Zealand in recent years. A revision of the national masonry code published in 1959 requires rational design of masonry in all but small buildings. This applies also to panel walls and partitions. Materials and workmanship are closely controlled and the standard of masonry constructed is high. Changes in the national earthquake code will require more masonry construction to be reinforced. Successful techniques have been developed for reinforcing concrete masonry. The development of these techniques is illustrated by reference to four buildings built in the period 1960 to 1964.

CONCRETE MASONRY IN NEW ZEALAND

There has been a rapid development in the use of concrete masonry as a building material in New Zealand in the last few years. Considerations of earthquake design are likely to increase this development rather than reduce it.

The concrete blocks are of a high quality, and high standards of materials and workmanship are being obtained in laying. Concrete masonry is cheap compared with other building materials. It produces aesthetic effects much appreciated by architects. A number of notable buildings have been built in New Zealand in recent years featuring concrete masonry. Two of these, designed by architects Warren & Mahoney, were recognised in 1959 and 1964 with the gold medal award of the New Zealand Institute of Architects.

Current changes in the New Zealand building bylaws for earthquake design will require masonry to be reinforced in nearly all buildings. Experimental development of reinforcing in concrete block masonry has been proceeding since 1958. Special blocks and techniques have been developed. Design methods have also been developed. These depend on rational elastic analysis using the same principles as in reinforced concrete.

Reinforced concrete block masonry buildings, depending on the masonry for load bearing and earthquake resistance, have been built in New Zealand up to 6 storeys in height.

MASONRY CODE

The design code controlling masonry design in New Zealand is the

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ational Model Building Bylaw NZSS 1900. It is in two parts. Chapter 6.2 relates to buildings not requiring specific design. Chapter .2 relates to design by elastic analysis. The code was first publihed in the present form in July 1959 as NZSS 95. It was rearranged s NZSS 1900 in July 1964.

Chapter 6.2 is limited to small buildings and dwellings. It ives maximum wall lengths and heights based on the principle that very wall is supported by another wall at right angles. The walls re tied by reinforced wall beams at floor and roof levels. There is o reference to diaphragm action by roofs or floors. The application f this Chapter to industrial and commercial buildings is limited to uildings of one storey and of roof span not exceeding 20 ft. (6.10 m.).

The majority of industrial and commercial buildings are designed o Chapter 9.2. This requires an elastic analysis to distribute loads according to the relative rigidities of all the elements in the uilding. Allowable stresses and slenderness ratio factors are given for both unreinforced and reinforced masonry. Allowable stresses are listed separately for construction with, or without, continuous inspection. The stresses are similar to those used in the Uniform Building Code published in California, U.S.A. There is no limit on height or wall thickness other than imposed by the stress requirements.

Chapter 9.2 also controls the design of masonry wall panels and partitions in framed structures. These have previously been designed by rule-of-thumb methods. Under Chapter 9.2 they are designed elastically, with certain concessions in allowable stresses. Infill panels are permitted twice the specified stresses for loads in the plane of the panel. Partitions are permitted twice the specified tension stresses for loads applied normal to the face. Despite these concessions, wall panels and partitions designed to allowable stresses prove to be more restricted in size, unless reinforced, than under the old rule-of-thumb design.

Masonry materials are closely specified by reference to other NZSS documents. Bricks, concrete blocks, sand, lime, cement, aggregate, slump and compression tests, and reinforcement are all controlled by individual standard specifications.

NZSS 1900 specifies mixes and mixing for mortar, grout and filling concrete. It specifies standards of workmanship for laying masonry, for placing reinforcement and for ensuring complete filling of grout or concrete round the reinforcement.

As a result of this detailed control by specifications, masonry designed and built to the New Zealand code NZSS 1900 is to a high standard.

EARTHQUAKE

Earthquake design is controlled by NZSS 1900, Chapter 8. This was first published in its present form in March 1955 as NZSS 95. It was rearranged as NZSS 1900 in July 1964. It is currently under revision and the revision is expected to be issued towards the end of 1964. A draft of the revision was published for comment in 1963.

In the revision two likely amendments will affect masonry design. One is a restriction on the use of unreinforced masonry. The other is the increase of the earthquake coefficient for loads normal to the face of walls, panels and partitions.

The restriction on unreinforced masonry will be related to the proposed three zones. In Zone A it will probably be prohibited altogether except for dwellings. In Zone B it will probably be permitted only for dwellings, one storey buildings, infill panels and partitions. In Zone C it will probably be permitted as for Zone B but with the addition of two storey buildings.

The earthquake coefficient is being increased for all zones for buildings of low period. In addition it is proposed that twice the basic coefficient be required for earthquake normal to the face of walls, infill panels and partitions.

Both these amendments have the effect of requiring much more masonry to be reinforced than previously. Walls, panels and partitions exempted in Zones B and C by the first amendment are very likely to require reinforcing to meet the second. Apart from this, there is a growing awareness amongst designing engineers in New Zealand that unreinforced masonry is an undesirable earthquake risk. In the case of concrete block masonry the cost of reinforcing is small compared with the improvement gained in earthquake behaviour.

In the early designs in concrete block masonry for multi-storey buildings reinforcement was provided strictly according to the requirements of the elastic analysis (Ref. 1). This meant that the upper stories were usually unreinforced. The building of Figure 4, designed in 1959, was built this way. More recent multi-storey buildings have been reinforced throughout. This applies to the buildings of Figures 3, 5 and 6.

CONCRETE BLOCK CONSTRUCTION

Blocks are made by most New Zealand manufacturers in a wide range of types and sizes. The basic block is $7\frac{5}{8}$" x $15\frac{5}{8}$" (20 cm. x 40 cm.) on face dimension and $3\frac{5}{8}$" (10 cm.), $5\frac{5}{8}$" (15 cm.), $7\frac{5}{8}$" (20 cm.), or $11\frac{5}{8}$" (30 cm.) wide. The mortar joint is standard at $\frac{3}{8}$" (1.0 cm.) thick, both horizontal and vertical. Most of the manufacturers list up to 60 different types of blocks. All blocks are hollow core.

In the last two years a special range of blocks has been developed to meet the requirements of reinforcing. Typical blocks in the 6" series are shown in Fig.1. Type 624 is used at vertical reinforcing, which is fixed and inspected before blocklaying starts. Type 625 is sed for horizontal reinforcing, with type 626 at the intersection ith vertical reinforcing. Types 627 and 628 are used at wall ends.

Special types not in the manufacturer's catalogue can be created y cutting with the carborundum masonry saw. This is sometimes neces- ary at return ends and raking gables. The cost of cutting is not igh.

Blocks are generally laid in running bond, although the same locks would be just as suitable for stack bond. Reinforcement is de- ormed mild steel bar of $\frac{3}{8}$" (10 mm.), $\frac{1}{2}$" (13 mm.) or $\frac{5}{8}$" (16 mm.) diam- ter. Vertical reinforcement is placed at 16" (40 cm.) or 24" (60 cm.) entres. Horizontal reinforcement is placed at 32" (80 cm.) centres. ometimes horizontal reinforcement is placed at wider centres, or omit- ed altogether between floors. There seems to be little clear evidence vailable as to the best arrangement of horizontal reinforcement. Some ests on 8'-0" x 8'-0" (2.44 m. x 2.44 m.) panels under raking load have een started at Christchurch to give more information on this point.

Mortar used for laying blocks is a cement : sand mix with a worka- ility agent. It has a minimum cylinder strength of 1800 lbs/sq.in. 127 Kg./sq.cm.) at 28 days. Cores containing reinforcement are filled vith concrete with maximum size aggregate either $\frac{1}{4}$" (6 mm.), $\frac{1}{2}$" (13 mm.) r $\frac{3}{4}$" (19 mm.) according to the size of the block. With all sizes of aggregate a minimum cylinder strength of 2,500 lbs/sq.in. (176 Kg./sq. m.) is obtained.

A very popular form of construction in New Zealand is the cavity wall. This consists of an inner leaf and an outer leaf, separated by a cavity of about 2" (5 cm.). The two leaves are connected by galva- nised wire ties. The cavity double wall has many advantages over a single wall. It excludes moisture and damp, it has a high fire resis- tance rating, it has low thermal conductivity, it is not subject to condensation on the inside, and it is a good sound barrier. Conse- quently the cavity wall is very widely used for all types of construc- tion.

In earthquake resistant design the cavity wall presents a problem in that the outer leaf is usually designed as a veneer, unreinforced and secured only by the wire ties. This problem has been met by rein- forcing the outer leaf and using a heavy quality tie. The tie is bent from 1" (2.5 cm.) wide mild steel strap, and is anchored firmly into the reinforced cores of each leaf. Both the reinforcing and the ties are hot dip coated in zinc because the outer leaf is likely to be damp. A typical arrangement of block types and reinforcing in a cavity double wall is shown in Fig. 2.

A recent development to improve the damp resistance of concrete blocks has been the incorporation during manufacture of a paraffin emul- sion. This is a Japanese invention and is marketed in New Zealand un- der the trade name Onoda N N. It is used in the mortar as well as in the block. Prior to this development it was standard practice to coat the exterior of blockwork with a waterproof paint or with a silicone colourless water proofer.

There is not enough evidence yet of the effectiveness of these damp-proofing methods to justify the omission of the zinc protection on the reinforcement of the 4" veneer, or on the ties.

RECENT BUILDINGS

Examples of New Zealand buildings in load bearing reinforced masonry for earthquake conditions are given in Figures 3 to 6. In each case the building has been designed to NZSS 1900, Chapter 8 for earthquake loading and NZSS 1900 Chapter 9.2 for masonry construction.

Figure 3 illustrates a 4 storey classroom block built in 1961, architects Warren & Mahoney. The load bearing elements are the masonry end walls and two parallel masonry walls in the centre of the building. The walls are in 7⅝" (20 cm.) reinforced concrete masonry with a veneer of 4½" (11.5 cm.) brick on the ends. Earthquake resistance is provided both ways by the masonry walls. For the longitudinal earthquake force the two walls in the centre of the building form the flanges of a stocky vertical I beam. The web is a short reinforced concrete wall in the centre of the building. The masonry was required for fire protection and sound resistance. It was the stiffest structural element in the building and logically became the load resisting element.

Figure 4 illustrates a 3 storey block of 12 flats built in 1960, architects Warren & Mahoney. This block is more fully described in Ref.1. The external walls are cavity walls with two leaves of 3⅝" (10 cm.) concrete masonry. Some internal walls are 7⅝" (20 cm.) concrete masonry. Floors are 5" (12.7 cm.) reinforced concrete slabs with 2'-0" (0.61 m.) deep edge stiffening beams. The walls are reinforced for the first and second storeys but unreinforced for the third storey. The roof is timber framed. The unreinforced walls conform with the design code requirements and were acceptable at the time because the available block types were not particularly suitable for reinforcing. Since then the open ended and other special type blocks of Fig.1 have been developed. Reinforcing is much easier and would now be used for all storeys.

Figs. 5 and 6 illustrate 6 storey blocks of flats built in 1963 and 1964, architect D.E. Donnithorne. In these the walling system is a 5⅝" (15 cm.) inner leaf and 3⅝" (10 cm.) outer leaf in exterior walls and 7⅝" (20 cm.) in interior walls. Floors are flat plate slabs 7" thick. The flats of Fig.5, built first, have no reinforcing in the outer leaf. This outer leaf is not included in the cross-section area of the wall when computing stresses. In traditional construction the outer leaf is only a veneer held by wire ties built into the mortar courses. This never has seemed a good earthquake risk. It was decided for the flats of Fig.6 to reinforce the outer leaf with ⅜" (10 mm.) rods at 24" (60 cm.) centres and improve the cavity tie as previously described. This construction detail is now becoming standard for cavity walls. Fig. 2 illustrates the detail.

The method of construction in the 6 storey blocks is very rapid and economical. Reinforced concrete work is confined to the slab plates, and as soon as a slab is poured the masons bring up the walls ready for the next slab. Vertical reinforcing is set in advance and horizontal reinforcing placed as the appropriate course is laid. Filling of concrete cores around the reinforcing is often done with a concrete pump. The concrete block is painted externally and internally and requires no other treatment.

THE FUTURE IN NEW ZEALAND

Current philosophy in engineering design recognises that walling materials must be assessed along with the frame in analysing behaviour in an earthquake. This quickly leads to the need to reinforce masonry walling materials for greater ductility. It is a short step from this development to make the walling materials the primary load bearing system and omit the frame.

Methods of reinforcing concrete block masonry have been developed in New Zealand through an experimental period lasting 6 years. These methods are now reliable and economical. Further details concerning this development can be found in Ref. 1, 2 and 3.

There are still some gaps, however, in engineering design information. More needs to be known about the best arrangement of reinforcing for earthquake ductility. More needs to be known about the behaviour of details such as bar laps for the best earthquake behaviour. More evidence is needed to support the adopted allowable stresses.

Some tests have recently been started in New Zealand, and it is hoped that more comprehensive testing programmes will follow.

Reference

1. Holmes, I.L. "Load bearing masonry design", N.Z. Engineering, Vol. 16, No. 1, Jan. 1961, p. 23.

2. Holmes, I.L. "Earthquake and concrete masonry", N.Z. Institute of Architects Journ., Vol. 30, No. 3, Apr. 1963, p. 43.

3. Symposium on Precast Concrete Components in Buildings, (Wellington, 1963) Papers by: Murphy, J. "Concrete masonry - responsibility of the manufacturer", Warren, F.M. "Concrete masonry - architectural", Holmes, I.L. "Concrete masonry - structural design".

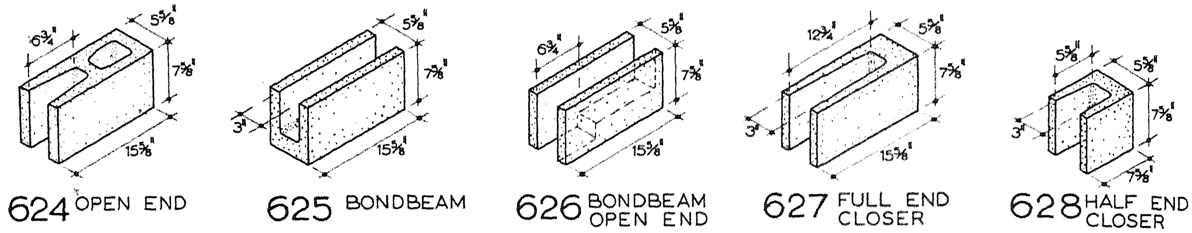

Fig. 1 BLOCK TYPES

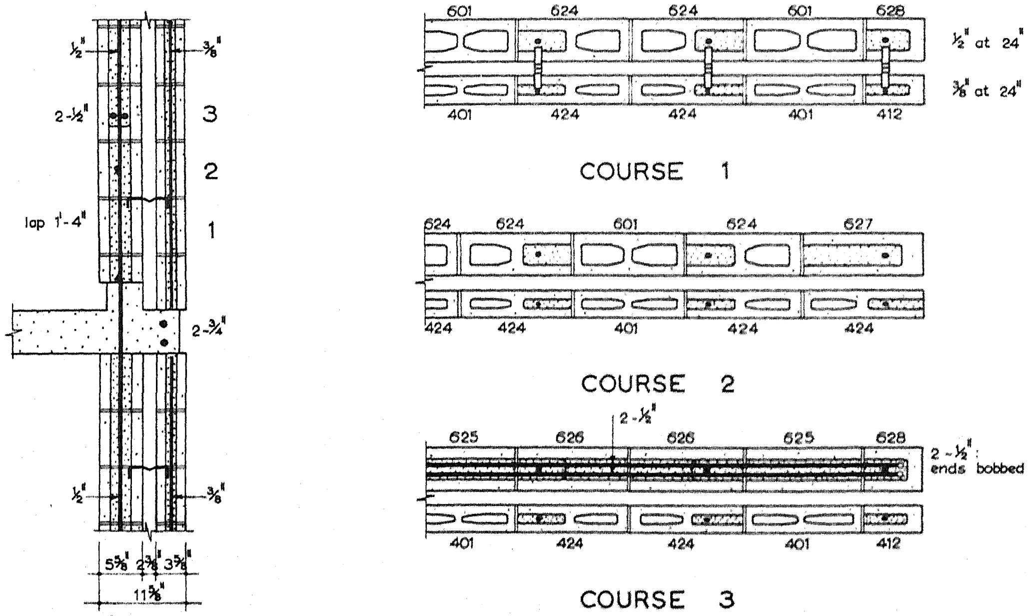

Fig. 2 REINFORCED CAVITY WALL

Fig. 3 Chapman Block, Christs College, Christchurch.

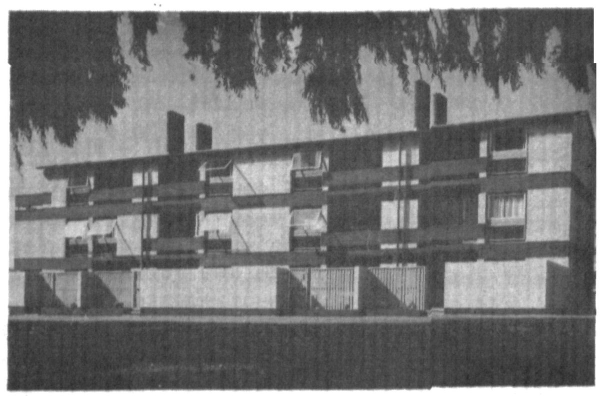

Fig. 4 Flats, Oxford Terrace, Christchurch.

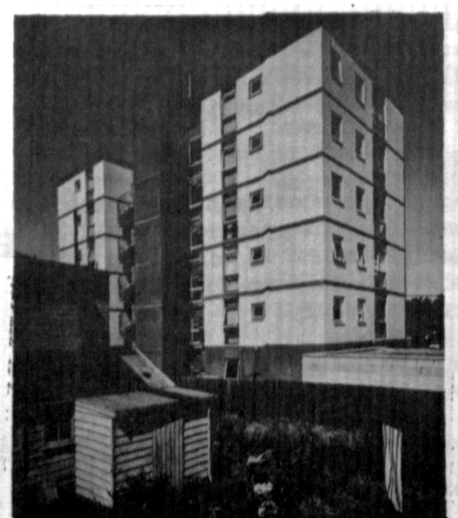

Fig. 5 Cambridge Court Flats, Christchurch.

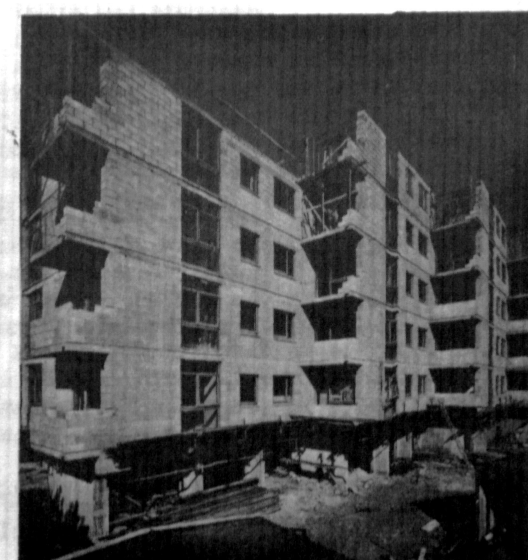

Fig. 6 Rolleston Court Flats, Christchurch.

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BY I.L. HOLMES

QUESTION BY: O.A. GLOGAU - NEW ZEALAND

I would like to comment on the remark that concrete masonry constructed to the N.Z. code is a high grade material suitable for multi-storey buildings. We use similar stresses to the Uniform Building Code but the requirements for the spacing of horizontal reinforcement are very much laxer than those of the Uniform Building Code, Title 21, or the Japanese regulations. Even if one reinforces far in excess of any code, say at 16" centers both ways this is still a very wide mesh compared to even the lightest reinforced concrete wall and a very much lower "ductility" must result.

AUTHOR'S REPLY: The performance of reinforced masonry in recent earthquakes indicates that even this light reinforcement might be enough. It must be remembered that the permissible stresses in masonry are much lower than in concrete and the bulk is correspondingly greater. For multi-storey buildings more reinforcement than the minimum of the New Zealand code is used, and horizontal reinforcement is placed at 32 in. centres. It is not sufficient to apply design rules from reinforced concrete. The spacing of bars in reinforced concrete was originally based on requirements such as shrinkage and watertightness rather than ductility. Ductility tests on reinforced masonry itself are required. My paper mentions tests recently started in New Zealand, and it would be interesting to know if the problem is being pursued in other countries.

QUESTION BY: G.H.F. McKENZIE - NEW ZEALAND

In view of the remaining design uncertainties which the author has set out on page 6 of his paper, I would like to ask Mr. Holmes whether he thinks it wise with our present state of knowledge to build up to 6 stories high in reinforced concrete masonry.

AUTHOR'S REPLY: Yes, I do think it wise, otherwise I would not have done it.

QUESTION BY: H.M. ENGLE - U.S.A.

1. Are concrete blocks manufactured with light weight aggregate?
2. Are all cells filled with concrete, or only those

containing reinforcing bars?

AUTHOR'S REPLY:

1. Mostly normal weight concrete is used, but pumice concrete blocks are available.
2. Only those cells containing reinforcing bars are filled, unless fire resistance or high stress intensities require otherwise.

QUESTION BY: G. WOOD - UNITED KINGDOM

One of the most difficult problems of earthquake engineering is to provide reasonable protection at a price people can afford. Many countries do not yet have the technical or financial resources to give any but the most elementary protection, and as a consequence the people are apathetic and accept earthquakes as acts of nature. They are unaware that anything can and should be done to alleviate their effects and dismiss the problem from their minds. Reinforced masonry provides a means of constructing ordinary buildings with ordinary labour. It is not difficult to lay down principles and rules based on sound engineering which ordinary builders can follow, as was done after the Quetta earthquake.

However, I think the greatest contribution this form of construction can make is in building up a tradition of anti-seismic construction. Rules and regulations tend to be evaded, whereas custom and tradition become entrenched so that earthquake protection will not only be built into men's homes but into their minds.

AUTHOR'S REPLY:

Reinforced masonry, like any new material, has its pioneering phase. My paper describes this phase in New Zealand. We have developed, and are still developing answers to the practical problems imposed. It is indeed hoped, as Mr. Wood suggested, that reinforced masonry will become a traditional form of construction in this country, with the consequent advantages to earthquake security.

QUESTION BY: E. Del VALLE - MEXICO

Is there any regulation in New Zealand concerning the maximum number of stories that a reinforced concrete masonry building should have? If there is not any regulation what is the maximum number of stories constructed up to now with this type of material?

AUTHOR'S REPLY:

There is no height regulation in New Zealand building bylaws, only the limits imposed by allowable stresses.

For government public buildings however, the Ministry of Works has a regulation restricting reinforced masonry buildings to two stories. The maximum number of stories constructed up to now under the building by-laws is six, but there is currently under design a 9 storey block of flats.

QUESTION BY J.F. BORGES - PORTUGAL

The available information on the behaviour of masonry walls seems to be insufficient to accept the use of masonry walls without frames for multi-storied buildings. The high rigidity of this type of construction implies very high seismic forces that produce cracking of the walls. After this cracking occurs, the resisting capacity of the building is much reduced. It is of paramount importance to obtain further information on this subject, mainly based on tests.

AUTHOR'S REPLY: This question relates to the basic design philosophy of my paper. If the walls have to crack before the frames resist the earthquake, why not design the walls as the prime resisting elements rather than the frames? Then leave out the frames. The ductility of the wall can be achieved by its reinforcing. If this is concentrated in the jambs and at the top and bottom of the wall, as is common for many reinforced masonry designs, the wall incorporates its own frame. If the wall is correctly designed the required strength and ductility should be obtainable without a frame. I agree with Dr. Borges that more information based on tests is of paramount importance.

QUESTION BY: D.S. HUNT - NEW ZEALAND

I would like to know what provisions Mr. Holmes has made against shrinkage of long masonry panels. Presumably a joint of some description would be used. Could he tell us what type of joint he would recommend, also the maximum spacing of the joints, and also, what would be the effect of this joint on the behaviour of the wall when acting as a shear wall during an earthquake.

AUTHOR'S REPLY: Shrinkage joints are not as critical for reinforced masonry as for unreinforced masonry. Reinforced masonry is usually associated with reinforced concrete slabs, beams and foundations. Similar principles as to spacing and detailing of joints are applied. In the buildings illustrated there are no panels large enough to require joints. Spacing of joints would be about 50ft. or greater, depending on the amount of horizontal reinforcing. The joint would be a sealed gap, or dowelled. The shear wall would be assumed to have a discontinuity at the joint.