REPAIR OF BUILDINGS DAMAGED BY THE 1969 BOLAND EARTHQUAKE

by

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SYNOPSIS

On the 29th September, 1969, at 10.00 p.m., the Western Cape in South Africa was severely shaken by an earthquake which caused damage estimated at R15 million ($18 million). This paper provides a general description of the damage caused to masonary structures near the epicentre, describes repair techniques and methods of surveying the damage and specifying the repair details.

INTRODUCTION

The epicentre of the quake was located in the mountain ranges north-west of Ceres - a distance of 100km from Cape Town. At first it was thought that the well known Worcester fault had shifted, but subsequently, however, the Bernard Price Institute maintained that a displacement had actually occurred along a minor fault quite close by. The seat of the quake was quite shallow and the magnitude on the Richter Scale was recorded between 6,5 and 6,8. From the nature of the damage in the vicinity of the epicentre the intensity of the quake was estimated as being between MM VII and MM VIII on the Modified Mercalli Scale. In certain instances it was possible to estimate the ground acceleration and it was found to vary between 0,16g to 0,20g with damage to masonary structures being reported within a radius of 300km while the tremors were clearly perceptible in the alluvium of Durban - some 1500km away. During the first month 72 aftershocks were recorded and these continued at a decreasing tempo. On 14th April, 1970 a severe aftershock of 6,5 on the Richter Scale caused further damage and this tremor highlighted the necessity for adequate repair methods to be employed in repairing earthquake damaged structures.

INSPECTION OF DAMAGE

The small farming communities of Ceres, Wolseley and Tulbagh which were located near to the epicentre of the quake suffered extreme damage. The extent of the damage was increased due to the age of the buildings and the poor building materials used in their construction. An inspection of the disaster area indicated extensive damage or total collapse of old buildings constructed of sun-dried bricks set in mud mortar. Some of these structures dated back to 1750. Severe cracking occurred at wall intersections and in many cases the external corners collapsed completely. End walls parted from the return walls and frequently collapsed outwards. Gables and chimneys in most buildings collapsed causing additional damage. In these old buildings, where the walls remained standing, it was found that most of the mudplaster had been dislodged in large sheets, due to poor bond.

Total collapse of modern single storey buildings were quite rare. In general the crack patterns to the brick and plasterwork were clearly defined. Diagonal cracks usually occurred over doorways and window

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I Associate, Ninham Shand and Partners, Consulting Engineers.

openings, and formedXcrack formations between openings. Cavity walls suffered extreme damage. Parting cracks at the intersection of walls were very common due to poor bonding. Gables were frequently cracked at ceiling level and occasionally collapsed outwards. Chimneys and brick columns were often cracked but in most cases remained stable and in position.

Steel frame structures with brick infill panels or asbestos cement cladding performed very well and no real damage was observed or reported. In the Disaster Area there were only a few reinforced concrete framed structures and these in general received only slight damage. Double storeyed houses and 2/3 storeyed blocks of flats which consisted of reinforced concrete floor slabs on a load bearing brickwork showed very little damage with the exception of the top storey which had crack patterns similar to single storey buildings.

Cracks appeared in the ground in many places, with concrete and tarred roads showing crack widths up to 30mm. Subsidences also occurred adjacent to rivers and stream beds. Large floor slabs such as occurring in factories and cold stores, indicated that large horizontal displacements had taken place. In some cases the joints between the floor panels showed spalling while others had widened.

CODE OF PRACTICE FOR REPAIRS

Southern Africa is relatively earthquake free when compared with the more active regions of the World with the result that the damage suffered by the buildings in the Disaster Area was unknown to the inhabitants. Numerous lightly and moderately damaged buildings were abandoned and in many cases demolished. Under these circumstances it was necessary to instill confidence into the members of the community as well as the Authorities set up for the rehabilitation of the area. After the first initial inspections it was found that opinions differed widely regarding which properties could be safely and economically restored. The necessity of a uniform Code of Repair soon became apparent. In order to formulate a common basis of action for engineers who had to draw up specifications for the structural repair work, a draft Code of Practice for the Repair of Earthquake Damage Buildings was drawn up during October, 1969 and issued by a Select Committee of the South African Association of Consulting Engineers.

This Code outlined the nature and typical appearance of the damage and gave a very simple and practical method of carrying out a preliminary survey on a standard survey sheet. It was recommended that concise details of the location and extent of damage and the estimated cost of repairs should be determined on Site. A globular "all in" rate of repair was quoted in order to "standardise" all estimates. It was also recommended that consideration be given to the replacement cost of the structure when deciding whether the structure should be repaired or not.

Temporary strutting of walls and other protective measures of avoiding deterioration of poor building materials were recommended for use in structures which were considered repairable.

Due to the prevailing sceptism and doubts of the inhabitants it was deemed necessary that all buildings should be repaired in such a manner that the repaired sections would be capable of withstanding an earth-

quake of at least the same intensity without endangering life. The Code accordingly recommended that the compressive and tensile strengths of damaged elements should be restored by pressure grouting of all cracks, the installation of wall ties and anchors, and the application of a high strength two coat mesh reinforced plaster using 10 SWG 150 x 150 square welded mesh on both wall faces. Special tests were carried out and the mix proportions for the plaster and grout was specified with PVA emulsions and Sika additives being used to improve the plaster bond and the fluiditity of the grouts. Two types of plasters were developed for the different types of brickwork.

The final section of the Code dealt briefly with the design and construction of new buildings in the Disaster Area and listed various dynamic factors which ranged from 0,1g to 0,5g, for different types of elements.

STANDARD SPECIFICATIONS AND REPAIR DETAILS

The preliminary surveys indicated that there were approximately between 2 000 and 2 500 damaged building complexes. Of these 25% were considered as "write offs", for which the owners were awarded cash settlements, while a further 40% were insured and had the choice of either carrying out their repairs individually or of joining the State sponsored Joint Repair Scheme.

The preparation of specifications and repair details involved a considerable amount of work as individual specifications had to be drawn up for each property. Due to the urgency of the work and the limited technical manpower it was imperative that a simple standard method of describing the damage and specifying the repairs should be evolved. Various techniques of recording the details of the damage and of specifying the method of repair to be carried out was attempted. Initial inspections revealed that the type and location of damage was very similar. Eventually ten standard Type Repair Details and a Survey and Repair Data Sheet were developed. By merely filling in the number of the Repair Detail on the Data Sheet in the appropriate column opposite the damaged element the manner and extent of repair was specified. This type of Data Sheet had the advantage that it was drawn up and completed in the field and that each Repair Detail specified was checked prior to the survey party leaving the building.

The following is a brief description of these Repair Details:

Types I, II, III specified the repair procedure to be followed in the cases of individual and multiple cracks to wall panels and the crack formations around window and door openings.

Types IV, V and VI gave the repair details for cracks at the intersection of partition and external walls, using mild steel tie bars in conjunction with a mesh reinforced plaster band.

Types VII A and B gave various details regarding the installation of mild steel and prestressed wall ties. The tie bars were preferably installed above the ceiling level where possible. At lower levels these tie bars had to be installed in recesses chased into the brickwork by means of a grinding disc prior to the application of the

reinforced plasterwork. In structures such as schools and hostels where long passageways occurred it was frequently necessary to tie the outer walls into the main structure by means of these tie bars. Where the internal walls did not coincide it was necessary to install the tie bars inside a galvanished mild steel sleeve. Endplates were welded onto these sleeves so that they would not only protect the tie bar but also provide a certain degree of bracing for the long unsupported walls.

Type VIII was applicable to the repair of gables and required the bracing of roof trusses in order to provide some lateral support for the gable walls. The cracks in the gable walls were repaired using a variation of the Type I detail and the gables were restrained from outward displacement by means of a number of tie bars.

Types IX and X specified the treatment for the repair of simple masonary chimneys and columns.

By using individual or a combination of these Type Details, it was found that the damage to most buildings was adequately and concisely covered. In a number of instances it was found necessary to adapt these standard Type Details in order to cater with a particular problem.

On the 14th April, 1970 these Repair Details were subjected to a full scale test when a severe aftershock of 6,5 on the Richter Scale occurred. An inspection of the repairs to a number of prototype properties already completed indicated isolated hair cracks in green plasterwork and a number of prestressed tie bars whose anchorages had failed.

CLOSURE

By the end of December, 1969 a large number of Building Inspectors had been seconded to the area and had completed the preliminary surveys and estimates of the damage. In April, 1970, the Authorities appointed the Consulting Engineers, Liebenberg and Stander,and Ninham Shand and Partners to implement a large scale repair programme. Due to the limited resources of the building industry in these areas it was immediately apparent that the local industry could not cope with this large volume of work which was spread over an area of 200sq.miles and unless the reconstruction was attempted on a massive scale these areas would be depressed for many years. A Consortium consisting of five of the largest contracting firms in South Africa was established and appointed on a cost plus a predetermined fee basis. Within two years this Consortium had repaired over 650 units at a total cost of R2,25 million. By the end of June, 1972 all buildings with the exception of about 10% of the buildings which were being repaired by private contracts had been completed.

These Repair Details which were developed for the repair of earthquake damaged structures have subsequently been successfully applied to masonary structures damaged by fire. The Author has recently completed the repair of two building complexes which were ravaged by fire at approximately 50% of the replacement cost and within 30 to 40% of the time it would take to erect a new structure.

Date: 10/6/70.

Surveyed by: [signature]

REPAIR SPECIFICATION FOR THE PROPERTY OF BAARTMAN.
Lot No: 1748 Address: 25 ZULCH STR, CERES
INTERNAL REPAIRS

Contract Sect. 17/1
Property No: 1039.

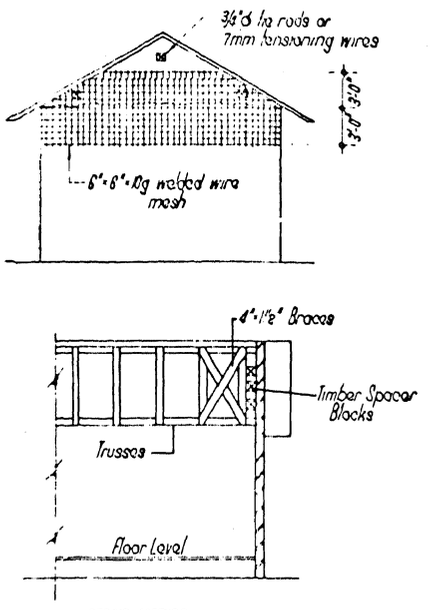
Room	Wall Item	Wall Detail	Doors	Windows	Corners Item	Corners Detail	Others Description	Detail	Estimate
9.	North		III		NW				
	East			III.	NW		Floor has sagged. Beams to be wedged & fixed.		
	South		III 2.		SE				
	West	I grout	III grout		SW				
10.	North			I	NW	IV	Damaged. Ceiling to replaced.		
	East	I.			NE	IV			
	South		III grout		SE		X 2 (2 cols cracked).		
	West			III grout.	SW				
11.	North		I & III.	I 2.	NW		Door damaged - replace.		
	East	I	III grout.		NE				
	South				SE				
	West	I.		I.	SW				

Remarks

House unoccupied (YES) NO
Temporary housing available (YES) NO

Cavity walls to be filled (YES) NO
Cracks to be grouted x

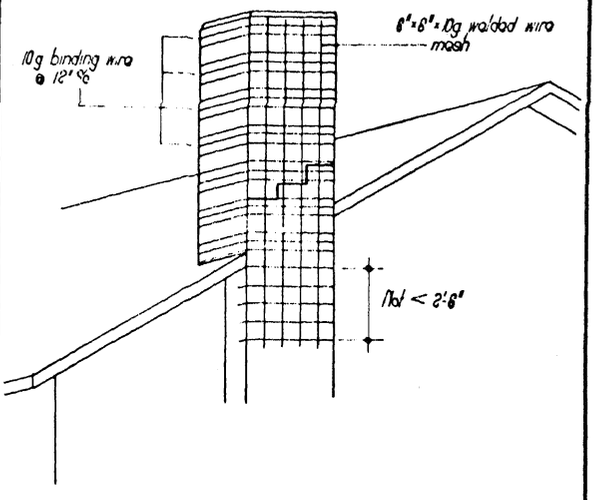
Note The purpose of repair refers to gables which have horizontal cracks and which are stable.



REPAIR METHOD

1. Chip down all plaster 3ft. on either side of the main cracks and roughen the surface of the cracks.
2. Fix 6"x6"x10g welded wire mesh on both sides of wall if possible with 10g wire ties
3. Plaster with 2 coats plaster Mix A or B for baked and unbaked bricks respectively.
4. Drill ¾" holes for tie rods thread bars and complete as per type VII.

TYPE VIII - REPAIR OF GABLES

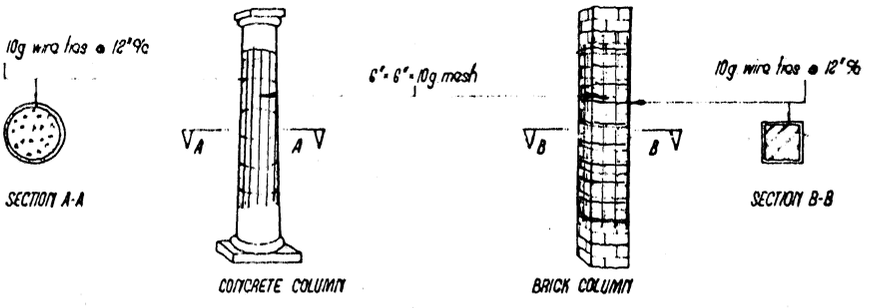


REPAIR METHOD

1. Chip down all plaster work.
2. Examine the brickwork if there is any doubt as to the stability or quality of the chimney then remove all damaged brickwork and rebuild with new baked bricks.
3. Wrap 6"x6"x10g wire mesh around chimney, carrying it to at least 2'0" below roof height. Add 10g. binding tie around chimney @ 12" c/c.
4. Replaster in 2 coats using Mix A or B for baked and unbaked bricks respectively.

TYPE IX - REPAIR OF CHIMNEYS

Note This type of repair refers to columns that are lightly cracked or alternatively the manner in which columns are to be strengthened after being rebuilt.

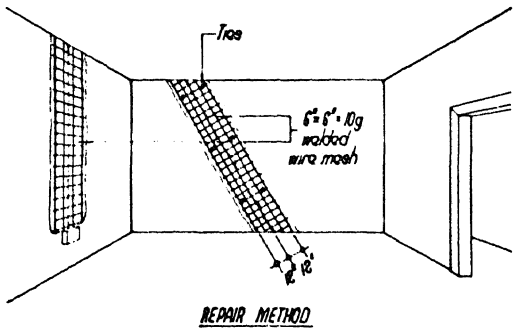


REPAIR METHOD

1. In the case of brick columns chip down all plasterwork and in case of circular columns roughen the surface wall
2. Wrap mesh around column and fix well
3. Fix 10g wire ties @ 12" c/c.
4. Replaster in 2 coats.

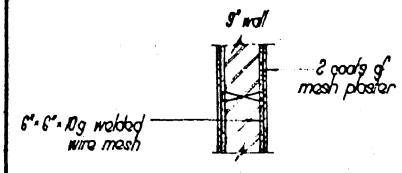
TYPE X - REPAIR OF COLUMNS

Note: This type of repair refers to cracks in walls which otherwise are sound These cracks can vary from 1/16" to 1/4" in width.



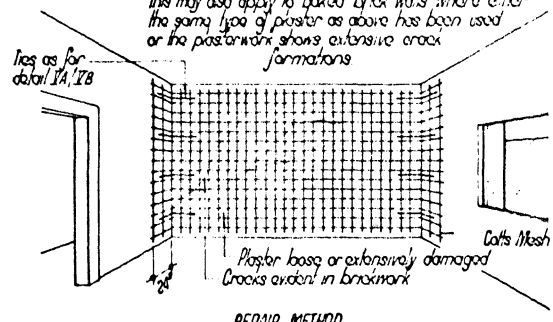
REPAIR METHOD

1. Chip down all plaster for 12" adjacent to crack
2. Chip out crack and grout if possible
3. Fill 6"×6"×10g. welded wire mesh with 10g tie wires
4. Plaster with 2 coats Mix A or B for baked and unbaked bricks respectively



TYPE I - REPAIRS OF MINOR OR ISOLATED CRACKS

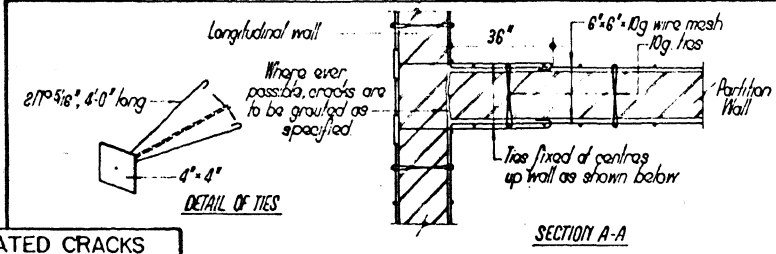
Note: Type II repairs refer to walls which originally were plastered with coats of mud and lime plaster and which have been loosened over large areas of the walls while the brickwork is stable and lightly cracked This may also apply to baked brick walls where either the same type of plaster as above has been used or the plasterwork shows extensive crack formations



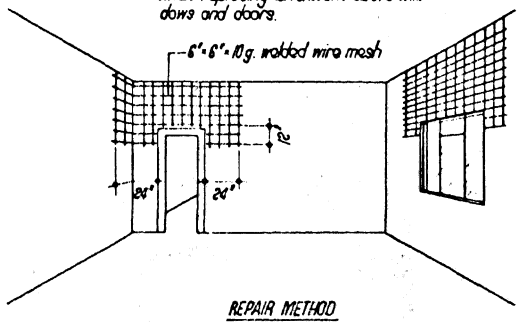
REPAIR METHOD

1. Chip down plasterwork over whole wall
2. Fix 6"×6"×10g wire mesh to walls using 10g tie wires, through predrilled holes in wall at approximately 4'-0" c/c both ways.
3. Apply 2 coats plaster using Mix A or B for baked and unbaked bricks respectively

TYPE II - REPLASTERING OF WALLS



Note: Type III repairs refer to areas above door and window lintels which contain a number of minor cracks Alternatively this type of repair must also be used when replacing brickwork above windows and doors.

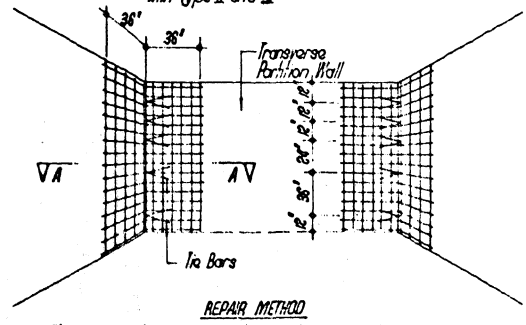


REPAIR METHOD

Note
1. Chip down all areas shown above, including all loose plasterwork
2. If necessary chip into the crack surface to roughen
3. Nail 6"×6"×10g welded wire mesh to both sides of prepared surface
4. Replaster in two coats using Mix A or B for baked and unbaked bricks respectively
5. Where the brickwork has been badly damaged and is loose, it shall be replaced if specified using new baked bricks. Mesh reinforcement and plaster shall be applied in accordance with Note 3 and 4 above

TYPE III - REPAIRS TO WINDOWS & DOORS

Note: This type of repair refers to wall panels which are in a sound condition but have been displaced from the adjacent walls This type may also be used in conjunction with Type II and V

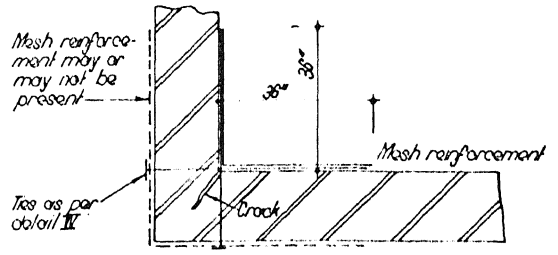


REPAIR METHOD

Note
1. Chip down plaster for a distance of 36" on the transverse partition wall and 36" on longitudinal wall at the corners on both sides of partition wall. Chip down plaster over 5'-0" on face of longitudinal wall opposite partition wall (see Section A-A)
2. Apply 6"×6"×10g wire mesh to exposed brickwork faces, and tie these through walls using 10g wire ties at 3'-0" c/c up wall.
3. Drill holes in longitudinal wall adjacent to corner of internals shown on elevation and fix ties through wall
4. Where practicable, insert plastic tubes into crack as specified
5. Replaster in 2 coats using Mix A or B for baked and unbaked bricks respectively
6. Grout crack using mixes specified

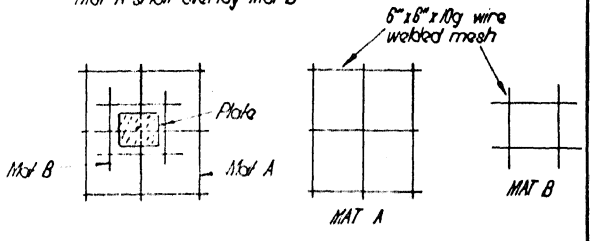
TYPE IV - TYING IN OF PARTITION WALLS

Note This type of repair is to be used when there are minor cracks apparent on inside of wall, but not visible on external face



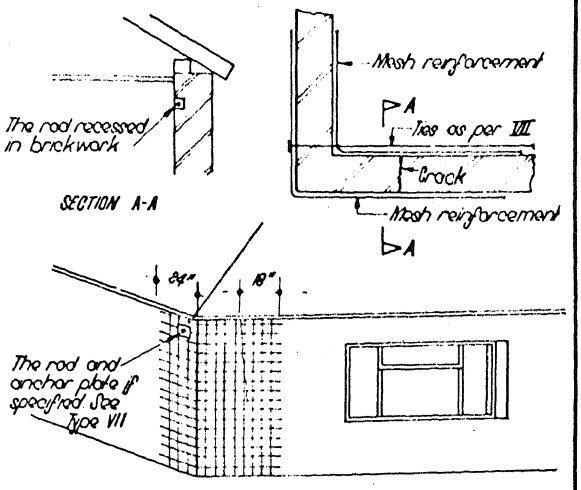
Ties as specified in type IV

Note In the event of there being no reinforcement on the outside face plaster shall be removed over an area of 12"x12" at each tie position and mats 'A' and 'B' shall be used.
Mat A shall overlay Mat B



TYPE V: TYPE V INTERNAL CORNERS

Note This type of repair refers mainly to corners which have only one vertical crack

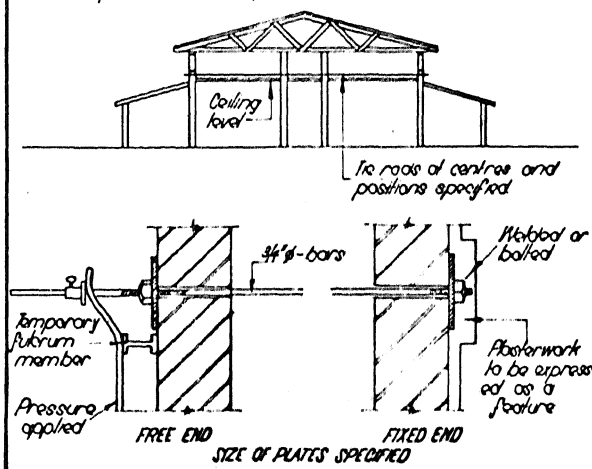


REPAIR METHOD

1. Chip down and remove all plasterwork as indicated
2. Chip open crack and inject grout as specified
3. Fix 10g x 6"x6" welded wire mesh to walls with 10g tie wires
4. Apply 2 coats plaster Mix A or B for baked or unbaked bricks respectively.
5. Tie rods as per type VII may be used with this detail where specified

TYPE VI: EXTERNAL CORNERS

Note These tie bars are used to maintain walls in present positions. No attempt shall be made to restore



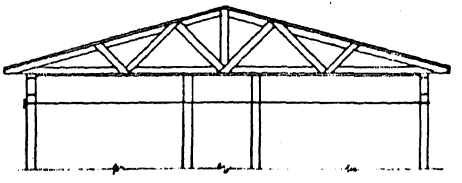
SIZE OF PLATES SPECIFIED

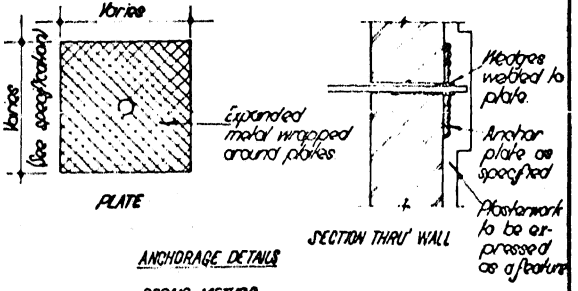
REPAIR METHOD

1. The attic wall shall be reinforced mesh plastered as given in Type II for a distance of 3ft at least on either of the tie rod positions
2. Drill 1¼" ø holes through walls and thread ¾"ø tie bars
3. Weld or bolt on the anchor plate at fixed end
4. Remove slack in the rod at free end, and fix to anchor plate by means of welding or other suitable methods
5. Paint with an approved protective coating and plaster over

TYPE VII A: MILD STEEL TIE BARS

Note These tie bars are used to maintain walls in present positions. No attempt shall be made to restore walls to original positions.





ANCHORAGE DETAILS

REPAIR METHOD

1. Walls shall be reinforced mesh plastered as specified
2. Drill ¾"ø holes through walls and thread 7mm ties.
3. Stress and weld the anchor to plate at both jacking and fixed ends.
4. Paint with an approved protective coating and plaster over.

TYPE VII B PRESTRESSED TIE BARS