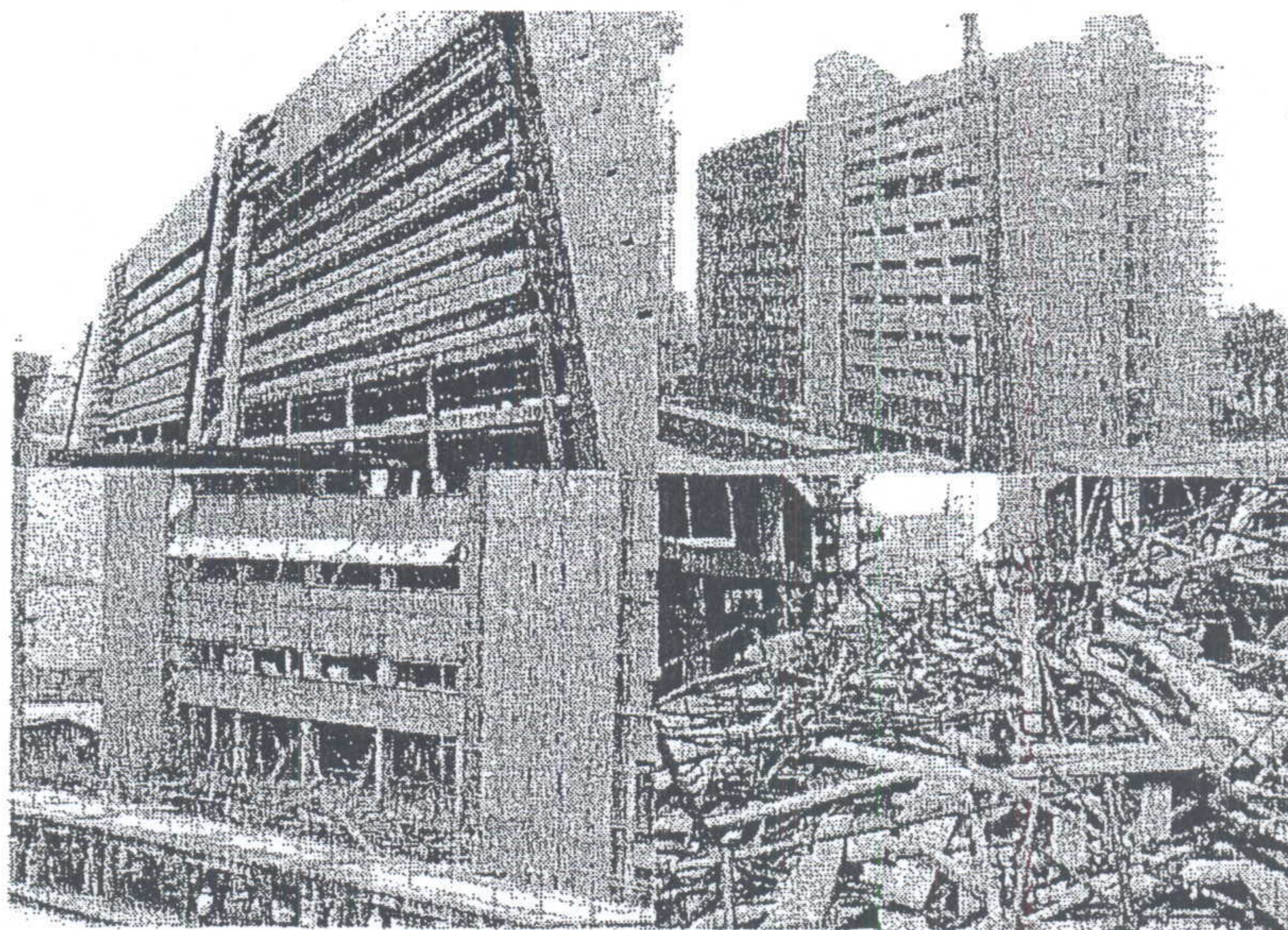


STRUCTURAL ASSESSMENT REPORT

COPY

ON

COLLAPSE OF SCAFFOLDING, AT THE SITE OF
THE NEW CUSTOMS & EXCISE BUILDING
GOVERNMENT CAMPUS, RICHMOND STREET
PORT OF SPAIN



DATED: 30TH OCTOBER, 2006

Prepared By

THE DESIGNS ENGINEERING BRANCH
MINISTRY OF WORKS AND TRANSPORT

MR. BRUCE FARLEY — CHIEF DESIGNS ENGINEER (Ag.)
MR. MONTANO GRAHAM — CIVIL ENGINEER II (Ag.)
MR. RICHARD FULCHAN — CIVIL ENGINEER I

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- It should be noted that persons on site indicated that the remaining scaffolding was erected in a similar manner to the collapsed section (see appendix I, pic. 3, 4 & 5). It appears that all scaffolding erected on and around the building utilized the Kwikstage scaffolding system (see appendix I, pic 6).

The structure appeared to be comprised of several components of structural pipe scaffolding standards (columns or vertical members), interconnected by transoms (double equal angles), ledgers, braces and tie bars. These members were used to support the horizontal steel-stages and timber battens (toe boards or treads) which directly supported the loads of the workers, materials and equipment (see appendix III, pg 4, Section 3 Definitions; appendix IV).

Prior to collapse the structure measured approximately 1.20 metres wide by 35.00 metres long by 35.0 metres high and was comprised of approximately eighteen (18) vertical lifts, interconnected using a wedge type system. This system relies mainly on friction to maintain the structural connectivity between the various horizontal and vertical components and structurally may be considered a modified pin system.

The entire structural frame was attached to the building utilizing a system of tie-members which was comprised of pipe scaffolding clamped around the external columns of the building. These

5.2 Literature Review

Having reviewed the documentation listed at section 3.0 Methodology the following items appear to be in contravention of BS 1139: Part 5: 1990 (see appendix III):-

5.2.1 Clause 4 : Materials

The clause states that materials used should be protected against atmospheric corrosion and shall be free of any impurities and defects which might affect their satisfactory use.

As outlined in the report on Material Testing a section of one of the samples (standard) extracted from the debris was corroded to the extent that there was a 70% reduction in wall thickness.

The report also indicated that this sample was modified and repaired.

Evidence of modified end connector elements were also observed throughout the debris (see appendix I, pic. 21 to 24).

The report on material testing also found that a high level of stress was introduced during the welding operation joining rolled steel and cast metal. This sample appears to be the end connector element of a transom (double equal angles), (see appendix II, pg 4,5,6,9,10 & 11)

5.2.2 Clause 11 : Basic Version

This clause outlines the minimum components that comprise the basic version of a scaffold.

The section indicates that adjustable base plates or equivalent components are part of this basic version.

However, on examination of the debris there was no evidence of the use of base plates or any equivalent components (as outlined in clause 9: Baseplates) at the base of the structure (see appendix I, pic. 17 to 20)

It should be noted that the submitted Manufacturers Technical Brochure listed previously at item 3.0 Methodology, does not appear to meet the requirements outlined in Clause 12 : Data Required From Manufacturer, of BS 1139: Part 5: 1990 (see appendix III).

Persons on or near the structure and witnesses indicated the following:-

- It should be noted that the majority of the debris is located centrally on the slab in the area where it was erected. This seems to suggest that the initial failure may be as a result of a combination of several factors.

The lack of bracing and inadequate bracing observed would have resulted in the structure being resistant to a certain level of horizontal loads imposed on it from the one end only. No load path or restraint was provided to loads imposed from the opposite end. This may have resulted in the structure swaying under load and imposing moments on the wedge connectors.

This system was designed to be static, that is, the wedge connectors are not designed or were never intended to function as full moment restraints.

The bracing for the frames were also connected to the standards at points above or below the wedge connectors, that is, where the ledgers and transoms were connected (critical node points). This may have resulted in the generation of moments or turning forces about these critical nodes.

The improper methods used to tie the scaffold structure to the frame of the building and the removal and changing of the tie-members resulted in:-

- i. No tie-members between the 6th floor or 7th storey and the roof of the building (see appendix I, pic 8. 15 & 16.).
- ii. The scaffolding being restrained for movement away from the building but free to move towards the building.

The entire system was located on a suspended reinforced concrete slab that had an uneven surface. The lack of base plates would have made leveling the first lift or vertical components of the structure extremely difficult. If this concrete surface was sloped or graded to facilitate the drainage of water, leveling the vertical components without base plates would have been even more difficult (see appendix I, pic. 17 to 20; Appendix IV, pg 4 "THE COMPONENTS", Adjustable Base and Head Jack).

The loss of material thickness caused by corrosion, the inadequate repair and or maintenance of certain key areas in the structure (see appendix II, tables 2A & 2B, pgs. 5.10 & 11), may have resulted in:-

- i. An adverse change in the component properties resulting in localized areas of the structure being compromised (see appendix II, Figure 3.).
- ii. An inability to attain the required fit necessary for the connector components to function as intended (see appendix IV pg. 3, "THE SYSTEM").

The resulting forces imposed on the wedge connectors, a modified pinned joint, would have put these sections and joints beyond the parameters for which they were designed resulting in a localized failure, which may have acted as a catalyst for further motion, and eventual failure of the entire structure.

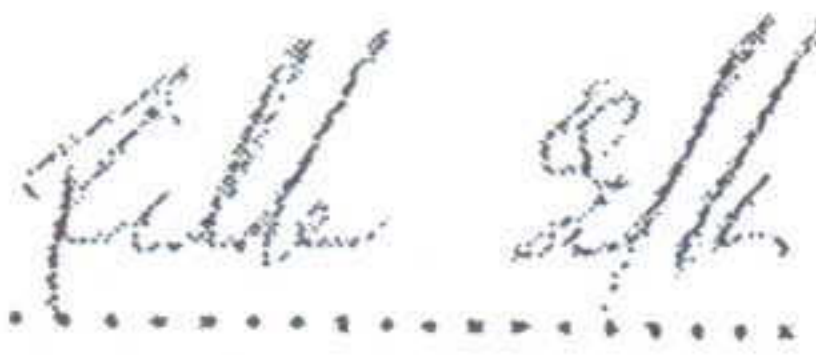
7.0 CONCLUSION

It is believed that the failure of the scaffolding structure may have been due to a combination of the following:-

- i. A lack of adequate bracing.
- ii. A lack of adequate tie back members to the building due to their removal during the installation of the solar panels.
- iii. The use of a less secure anchorage system at roof level during the installation of the solar panels.
- iv. An improper method of anchoring or tying the structure to the building frame.
- v. A lack of adequate base plates. This was necessary to properly level and vertically align the structure.
- vi. The adverse change in component properties caused by corrosion.
- vii. An inability to attain the necessary fit at the connection as a result of inadequate or improper repair or modification of the connection components.

It also appears that the scaffolding structure was in contravention of clause 4 "Materials" and clause 11 "Basic Version" of BS 1139 : Part 5 : 1990 "Metal Scaffolding".

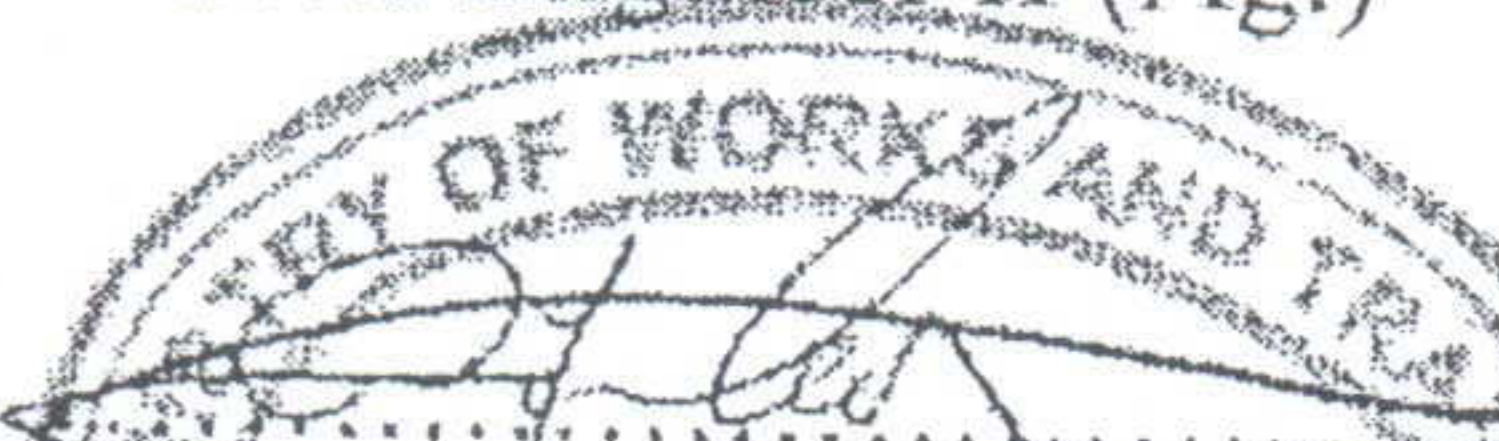
It should be noted that the submitted Manufacturers Technical Brochure does not appear to meet the requirements outlined in clause 12 "Data Required From Manufacturer", of BS 1139 : Part 5 : 1990.

Signed by: 

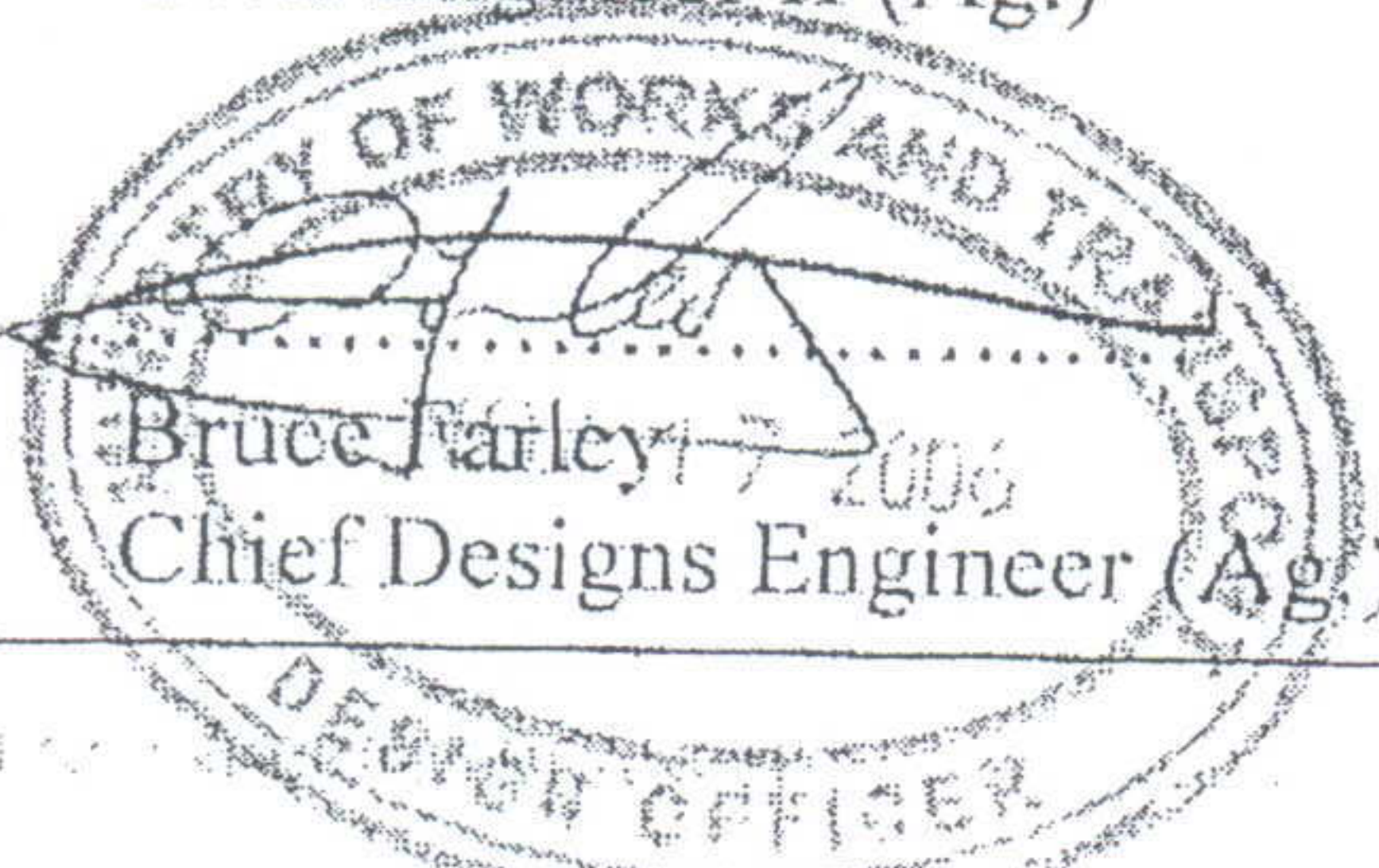
Richard Fulchan
Civil Engineer I

Signed by: 

Montano Graham
Civil Engineer II (Ag.)

Signed by: 

Bruce Farley
Chief Designs Engineer (Ag.)

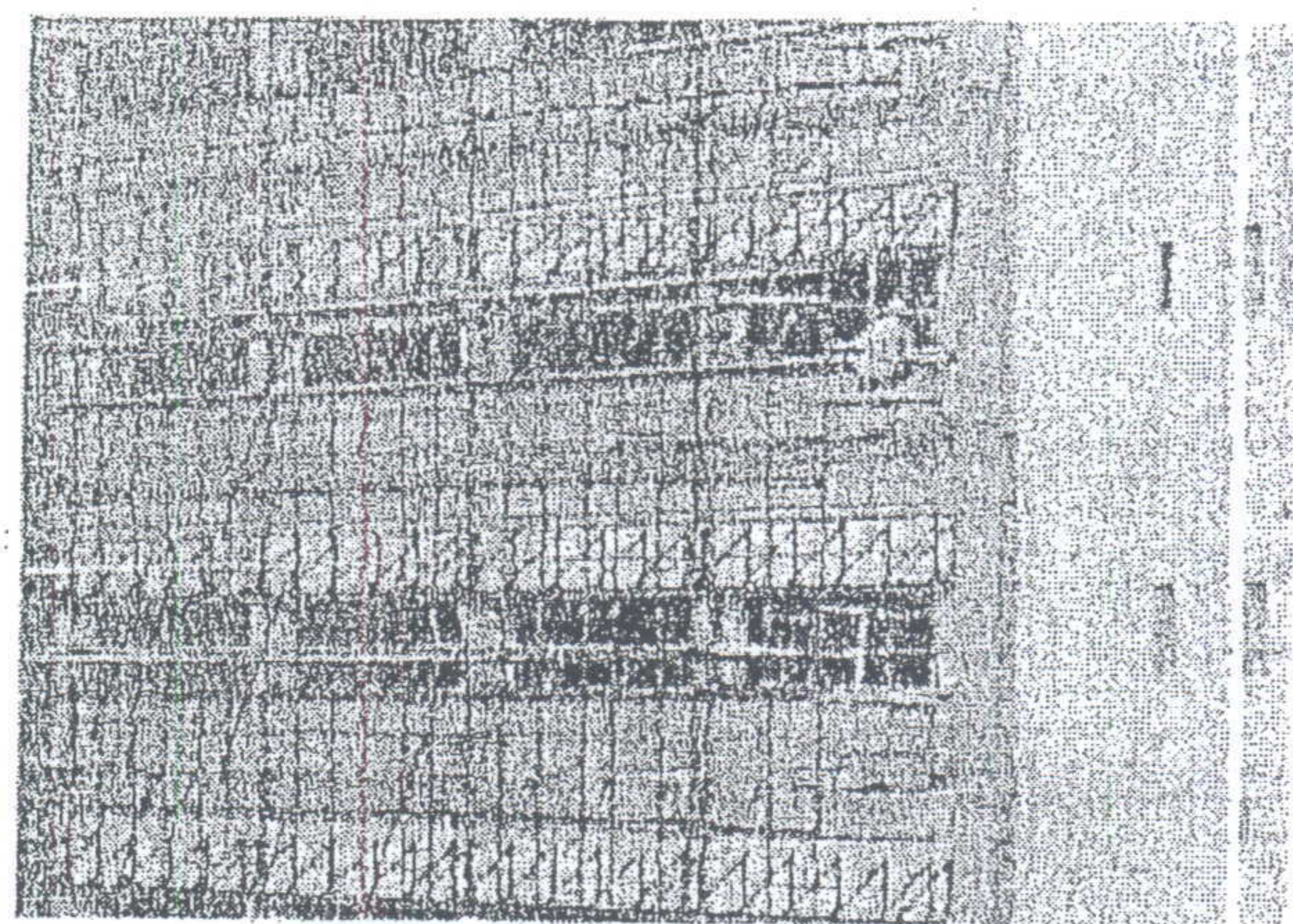


8.1 Appendix I

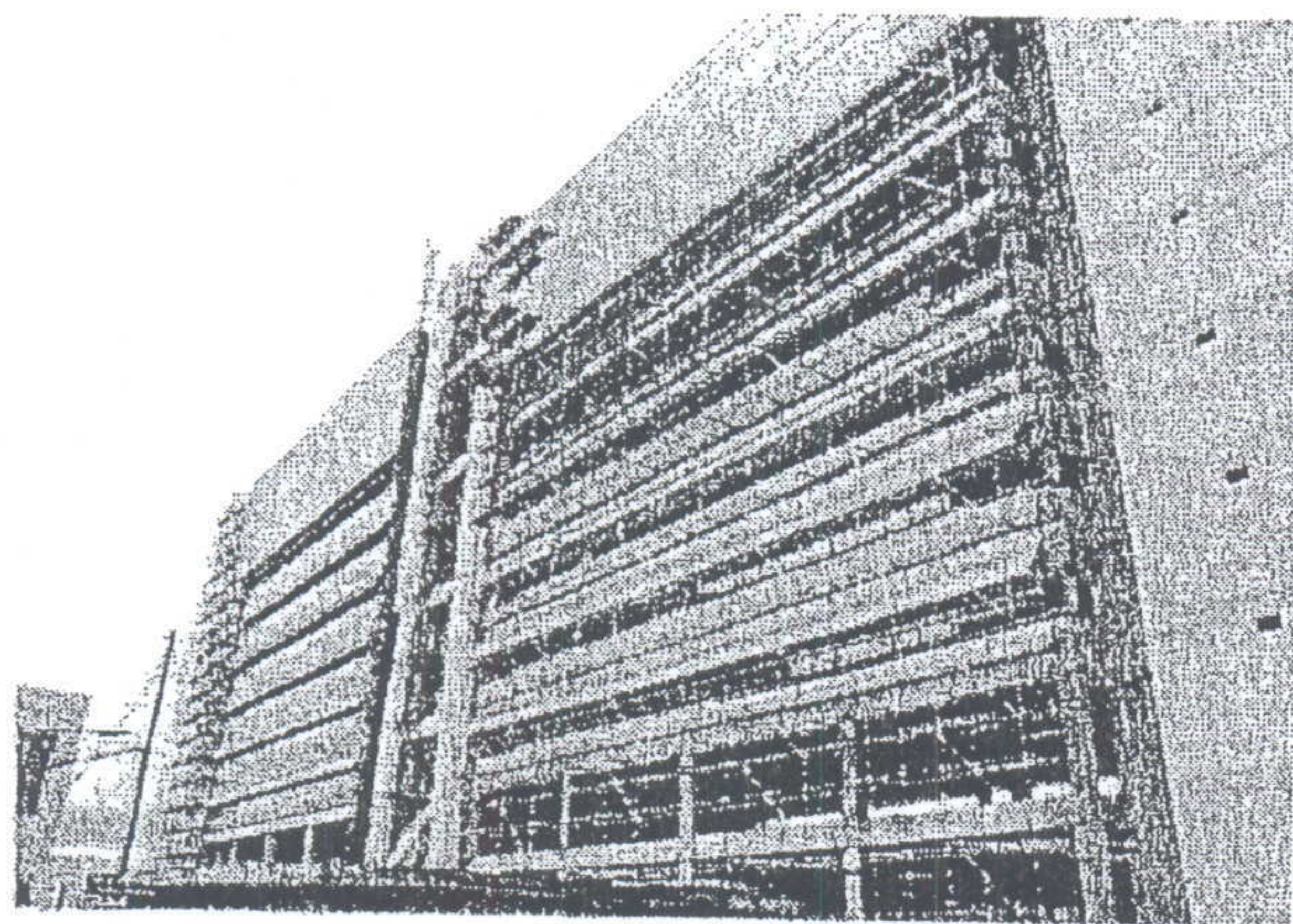
Photographs



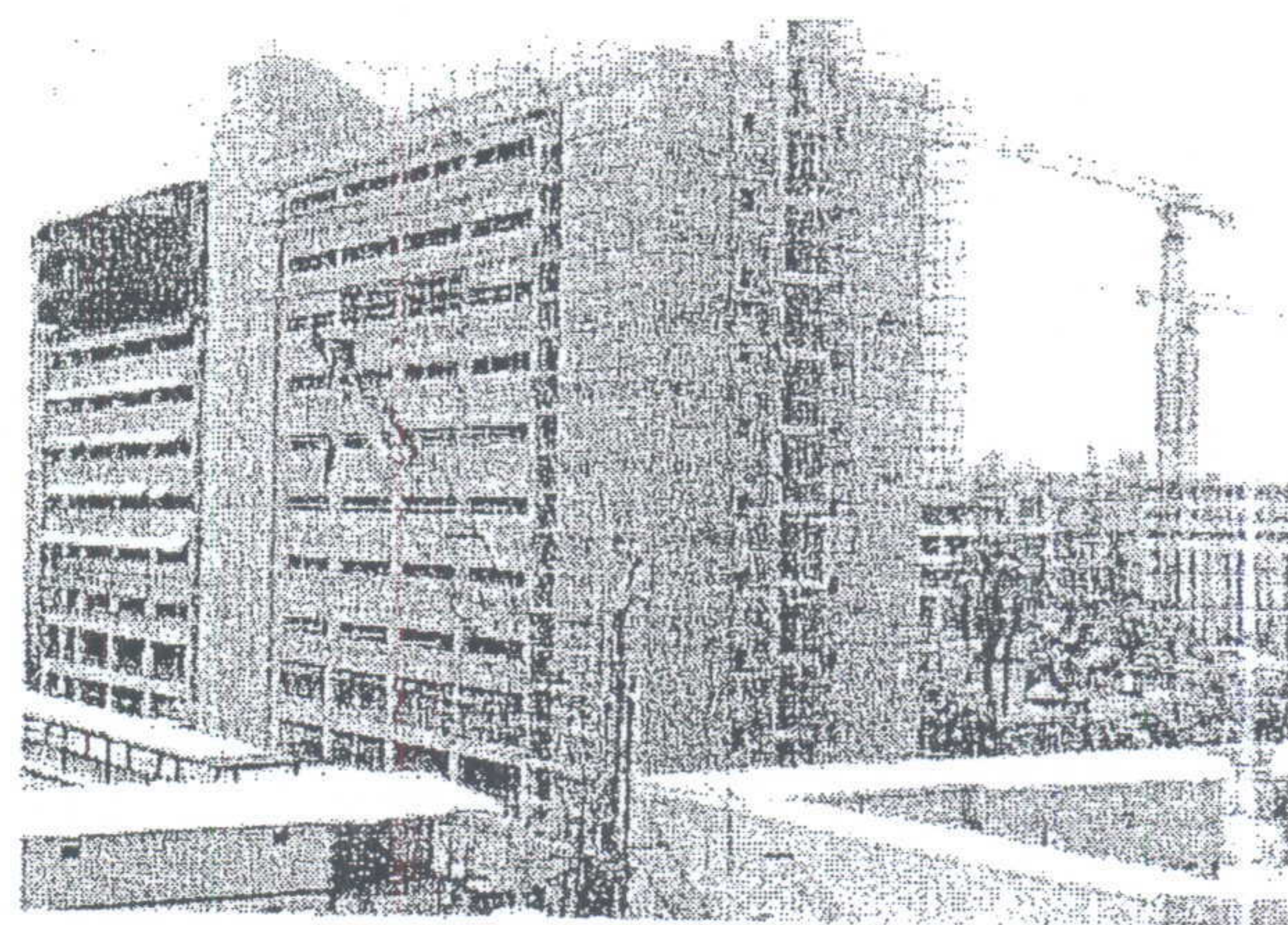
Pic. 1 East side New Customs and Excise Building
Note scaffolding erected on south side building.



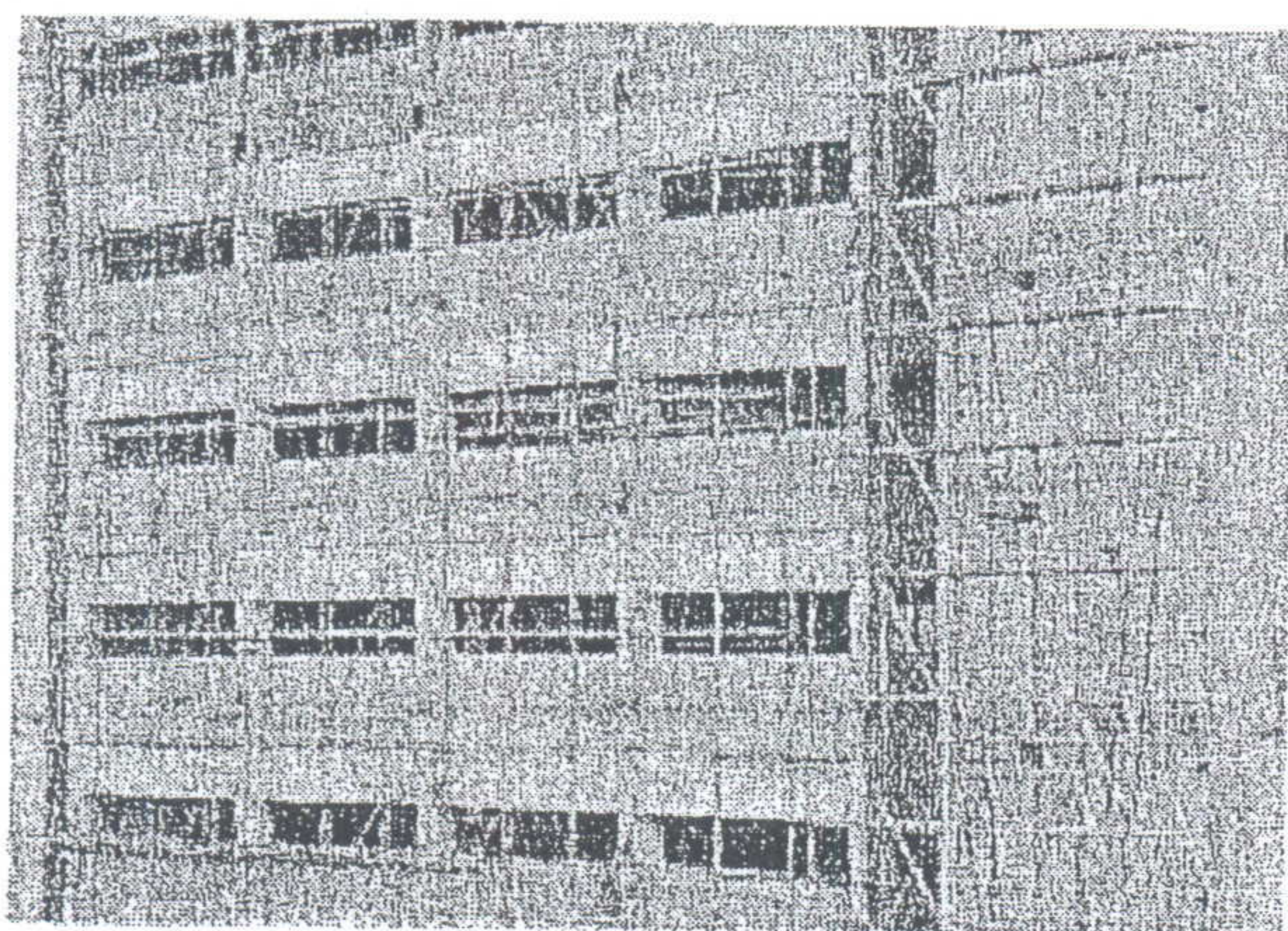
Pic. 2 Closer view of the scaffolding, south eastern side of building, prior to collapse.



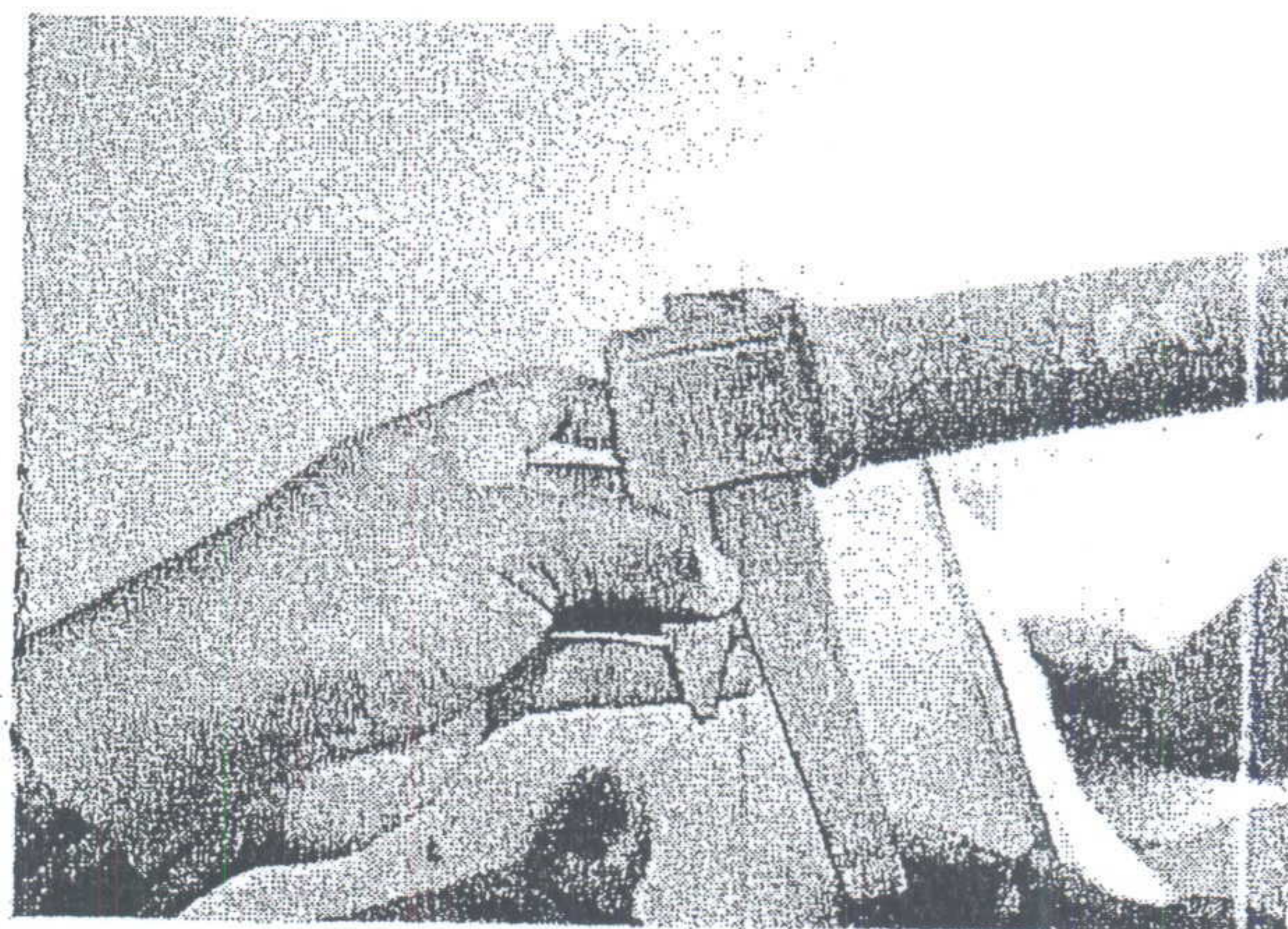
Pic. 3 West side New Customs and Excise Building.
Note scaffolding erected on south side building



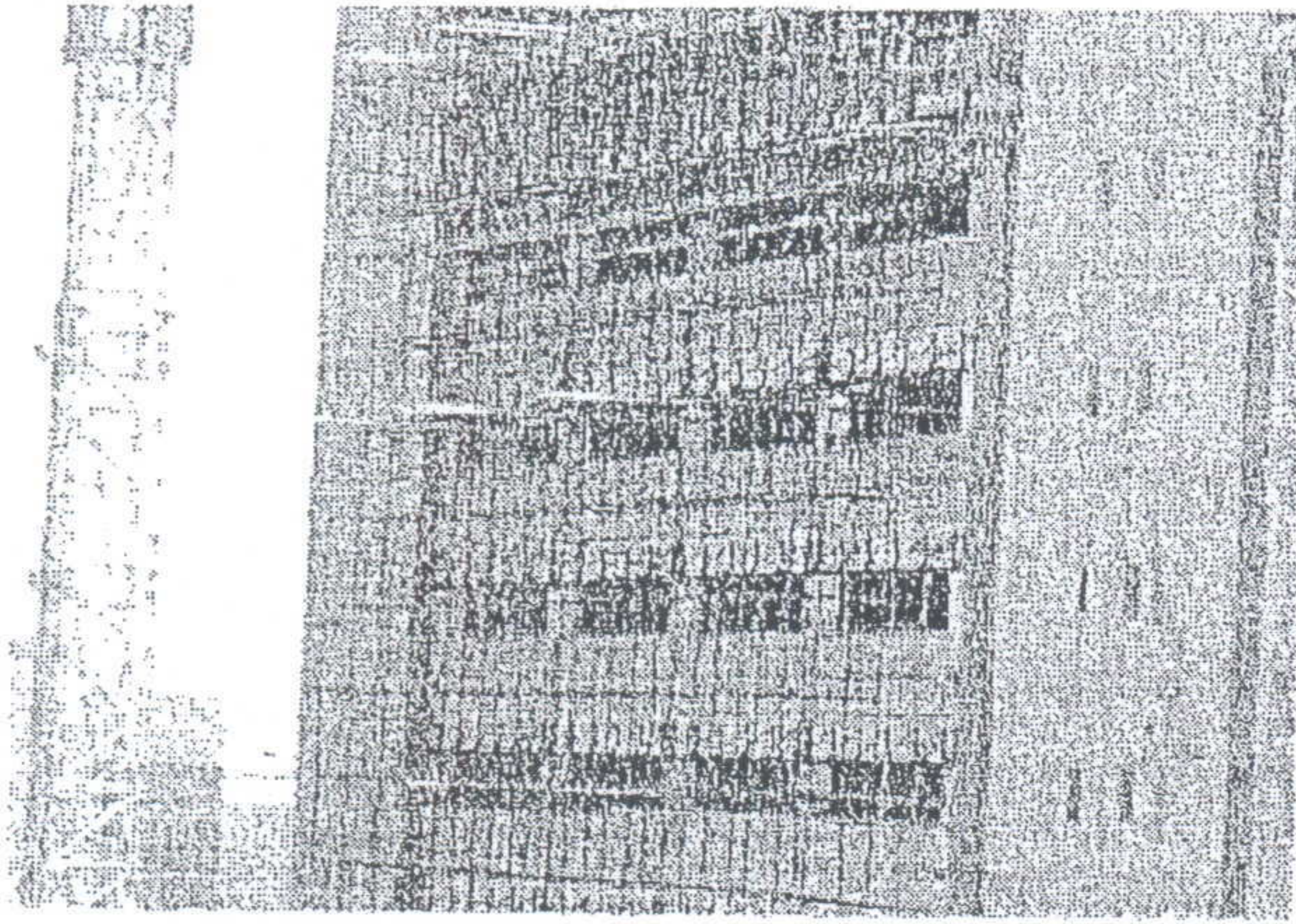
Pic. 4 North side New Customs and Excise Building.



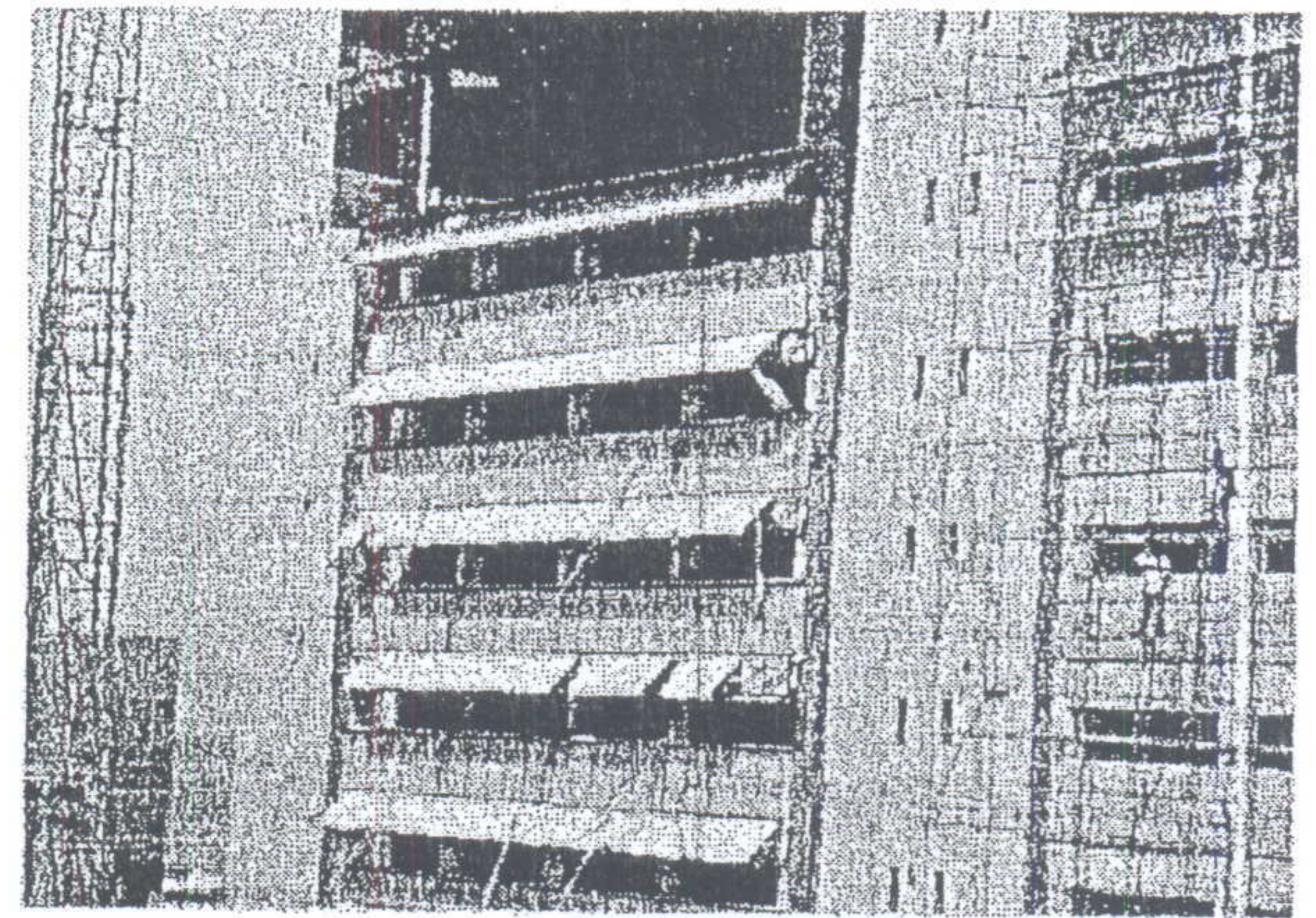
Pic. 5 Closer view of scaffolding on the north east side of building



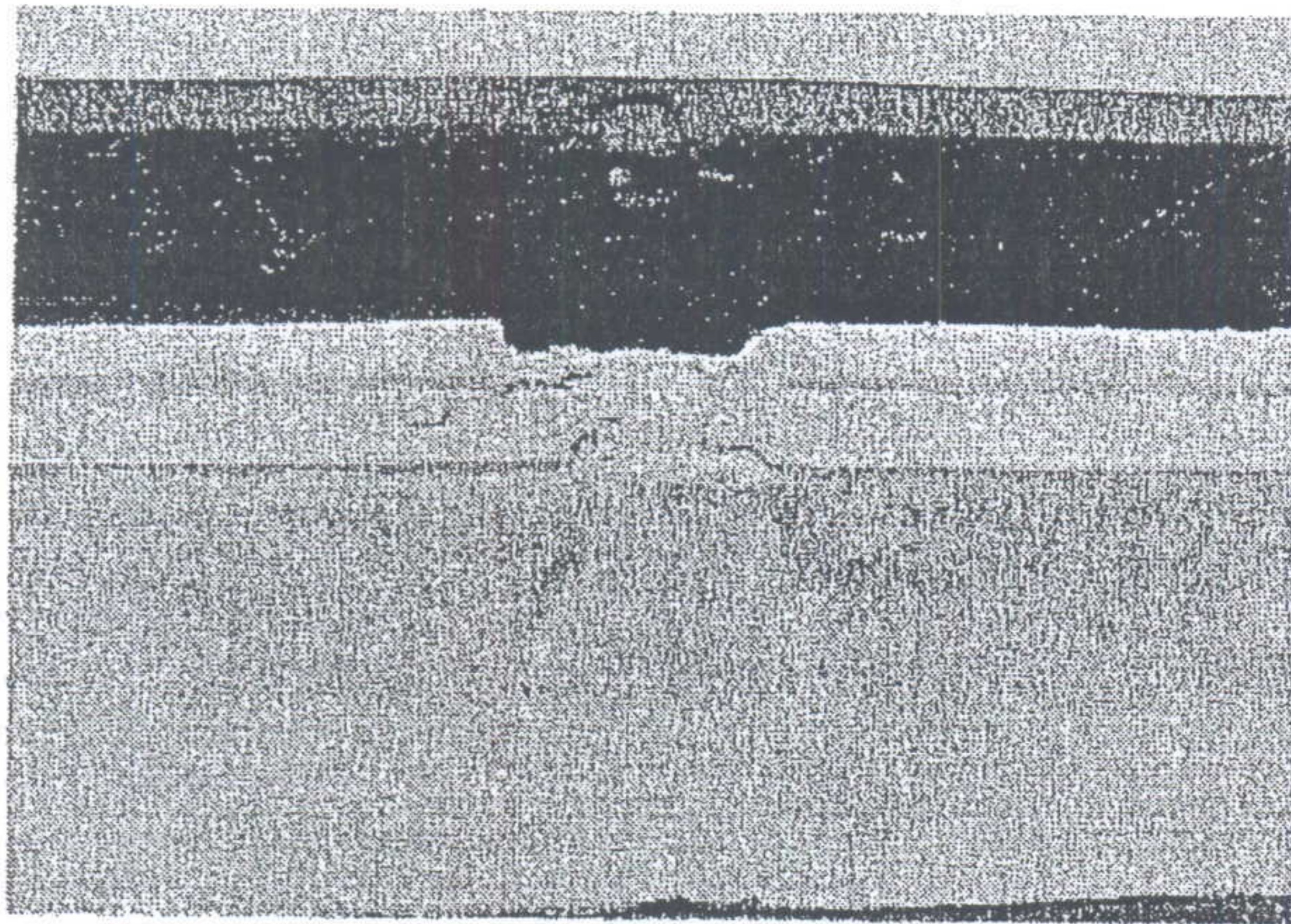
Pic. 6 End of ledger taken from collapsed debris.
Note system brand embossed on end.



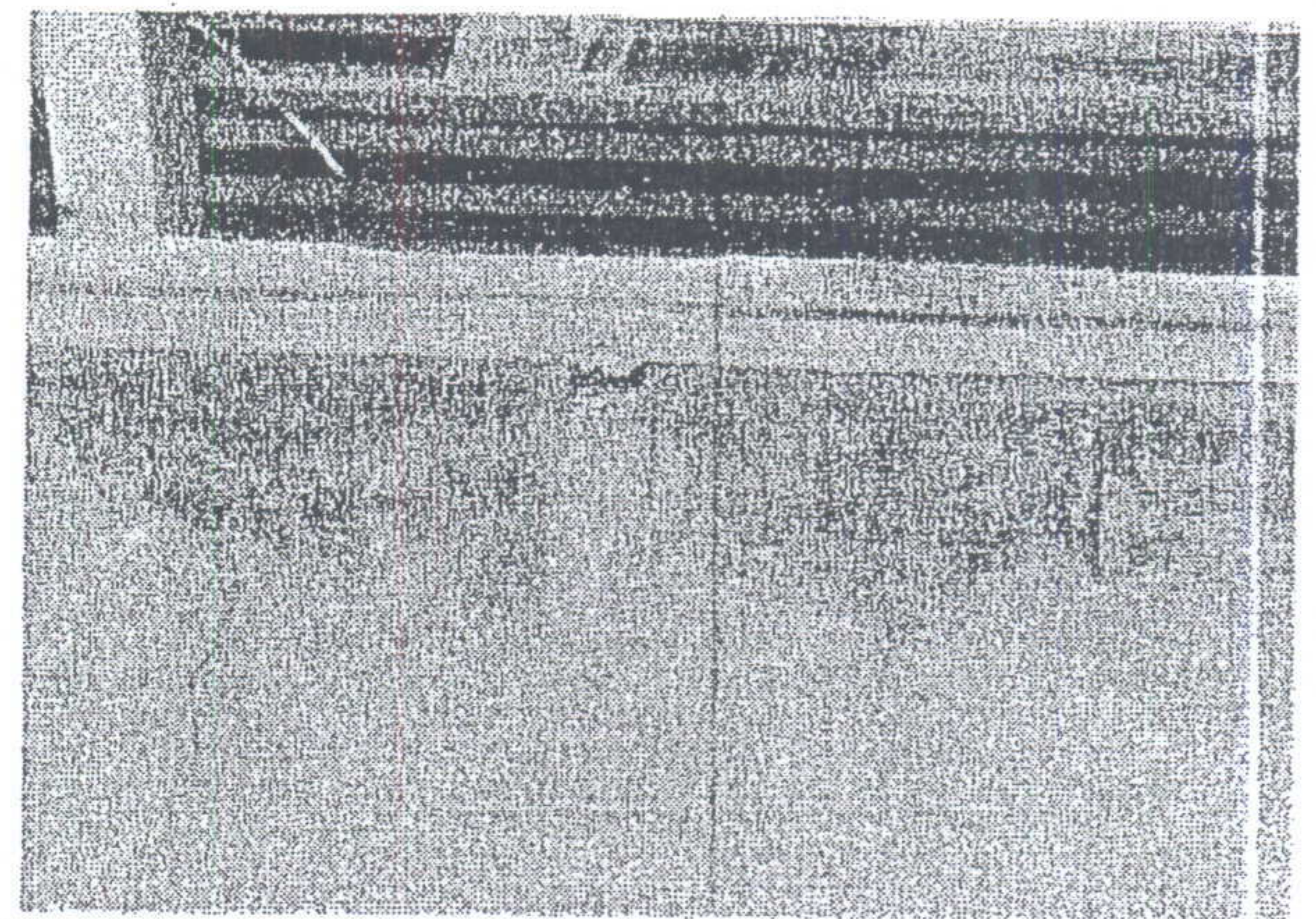
Pic. 7 Scaffolding on south eastern side of the building prior to collapse.



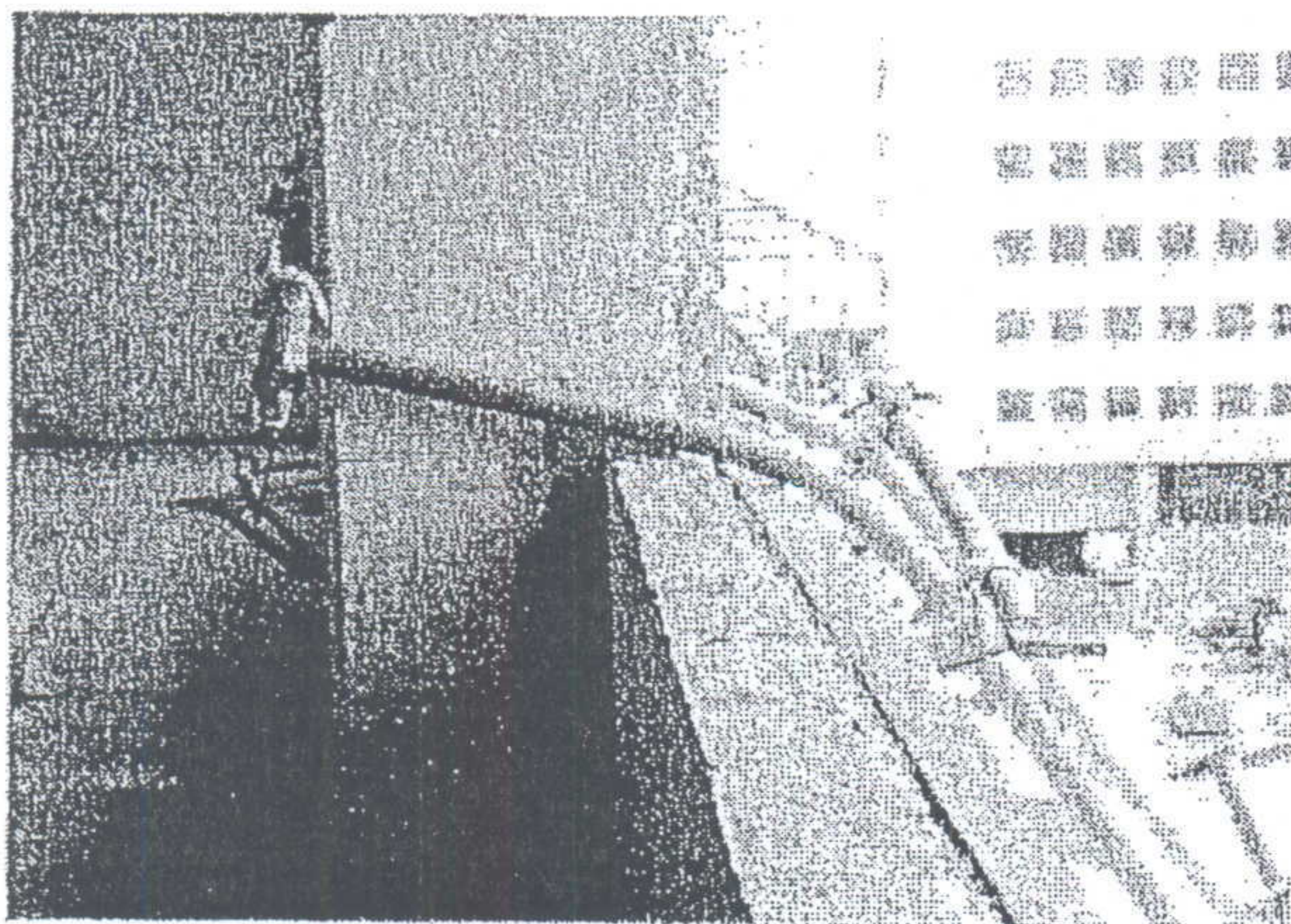
Pic. 8 The collapsed section of scaffolding. Note tie members visible on building.



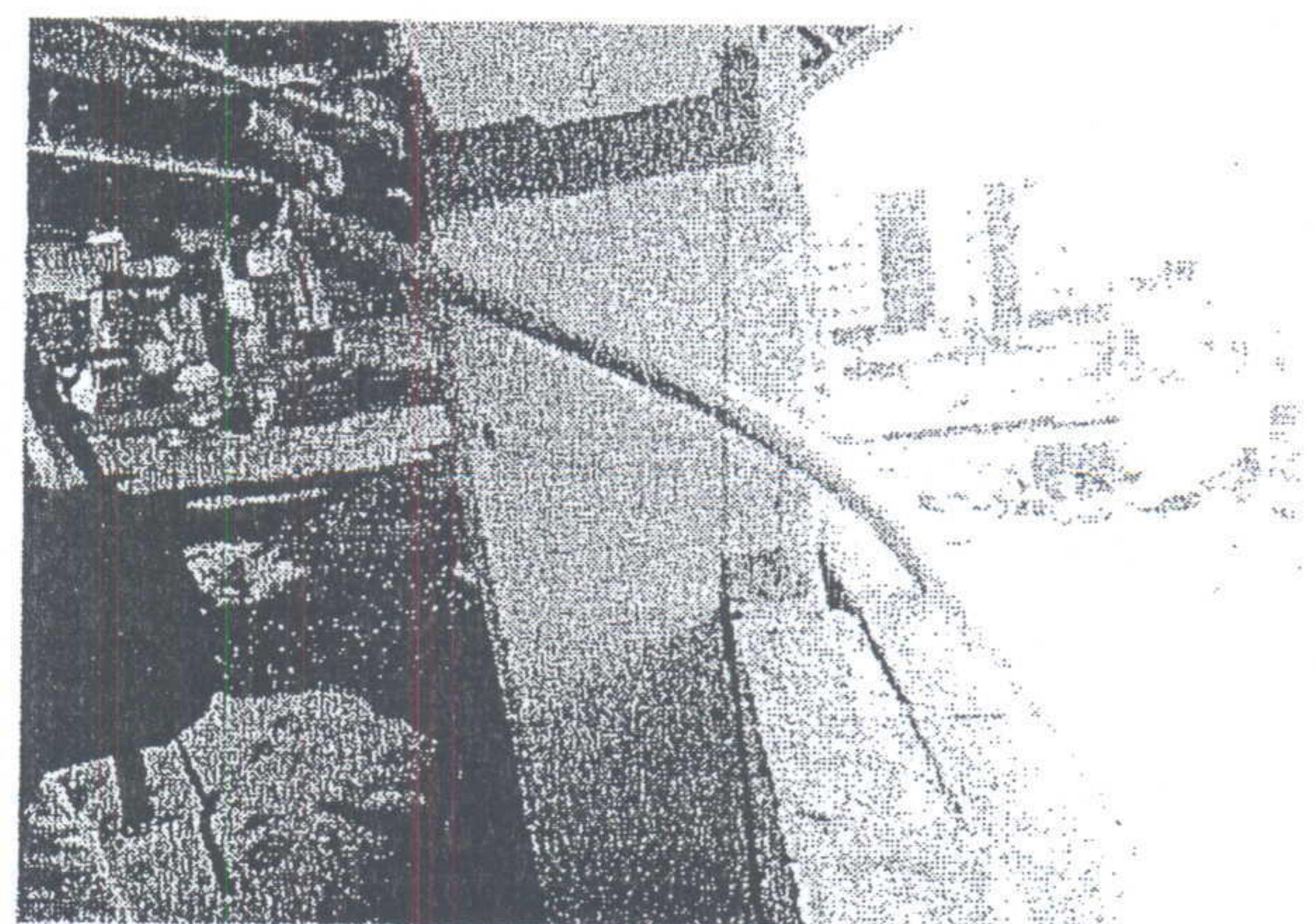
Pic. 9 Damage to mortar finish, center of parapet wall, south east side of roof, after collapse. Note lack of bolt holes or bolts.



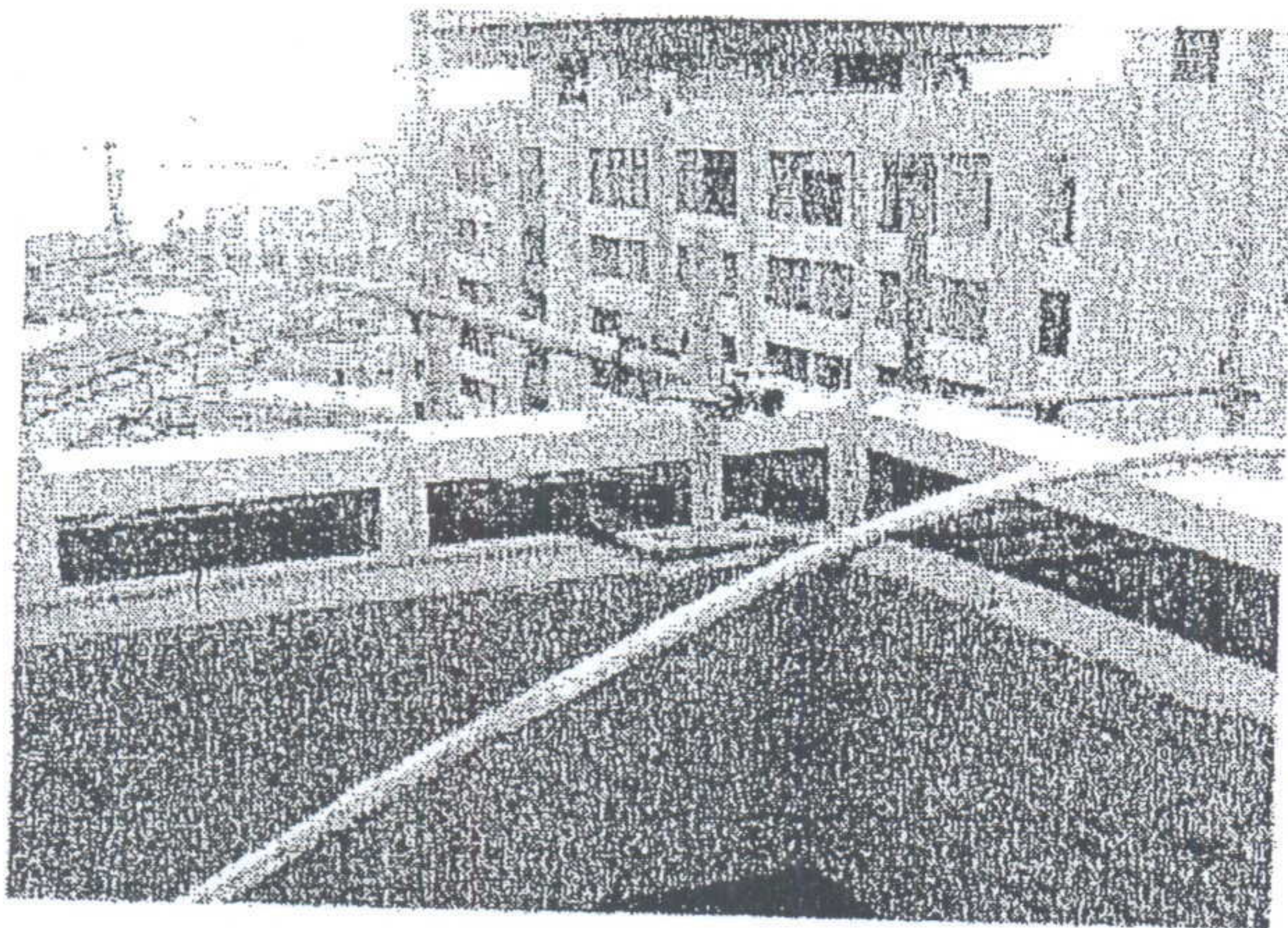
Pic.10 Damage to mortar finish left side parapet wall, south east side on roof, after collapse. Note lack of bolt holes or bolts.



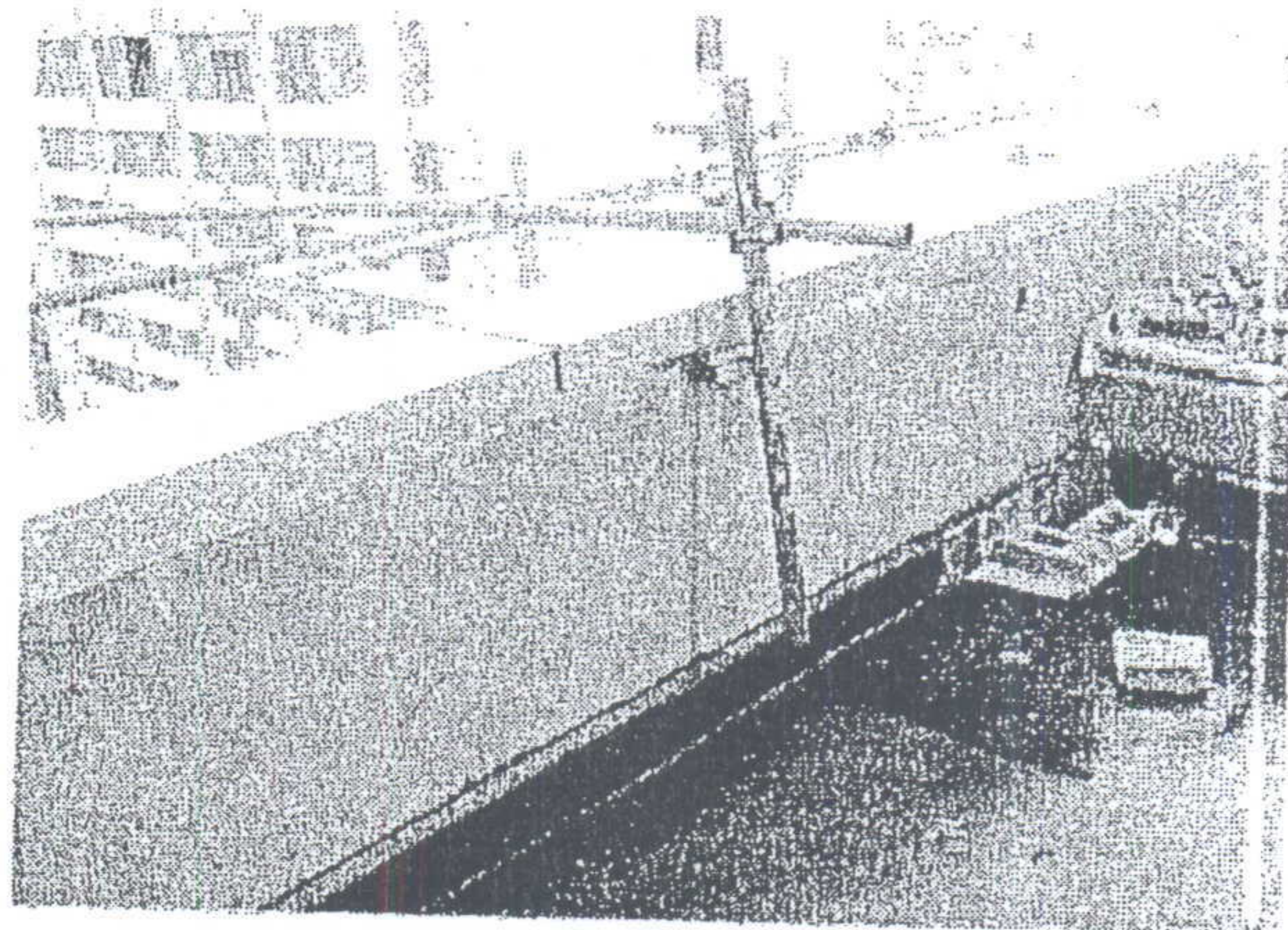
Pic. 11 Typical anchorages to column after collapse. Note the outer clamps and pipes on tie members away from column face.



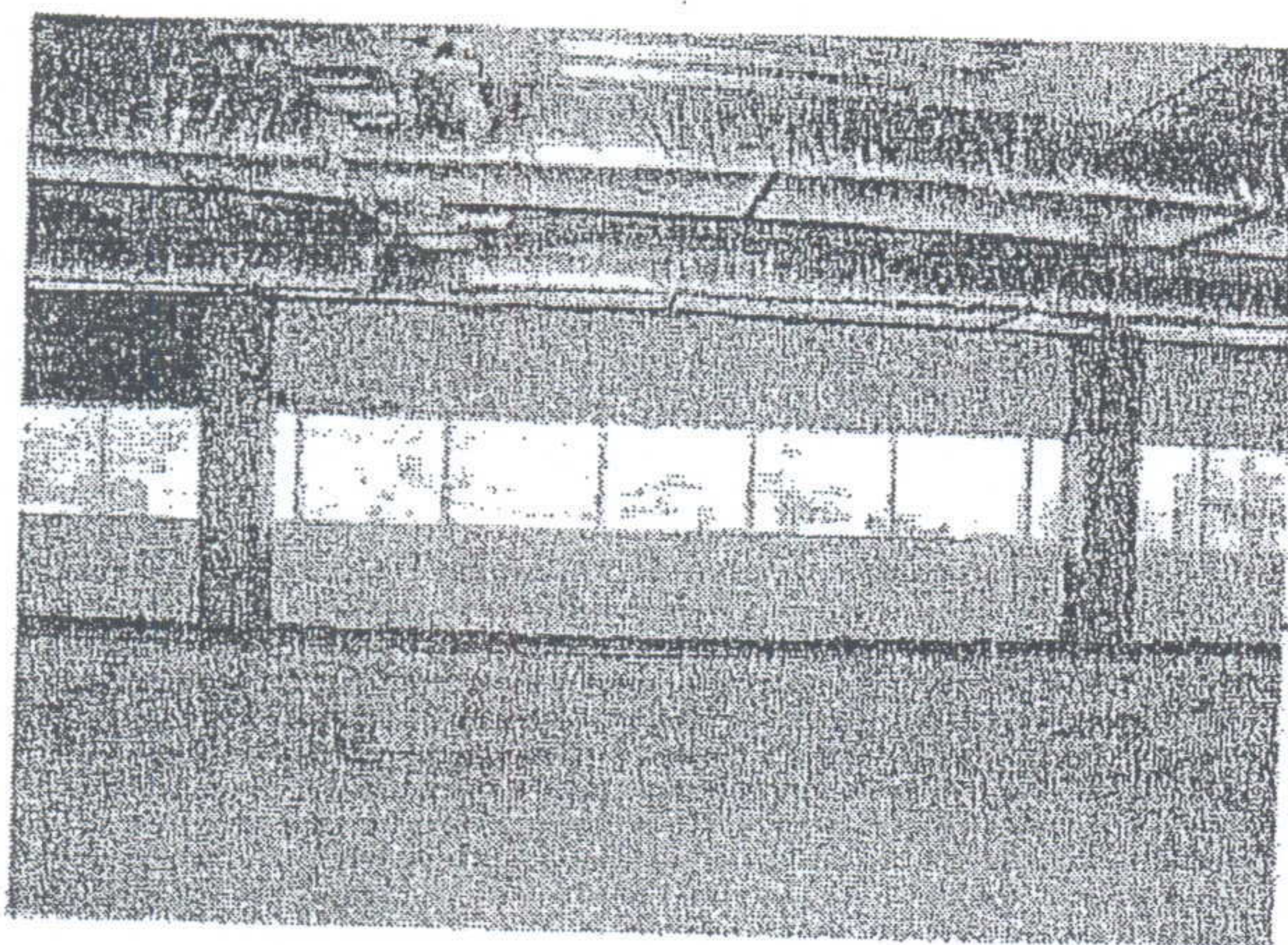
Pic. 12 Typical anchorages to column after collapse. Note the outer clamps and pipes on tie members are missing.



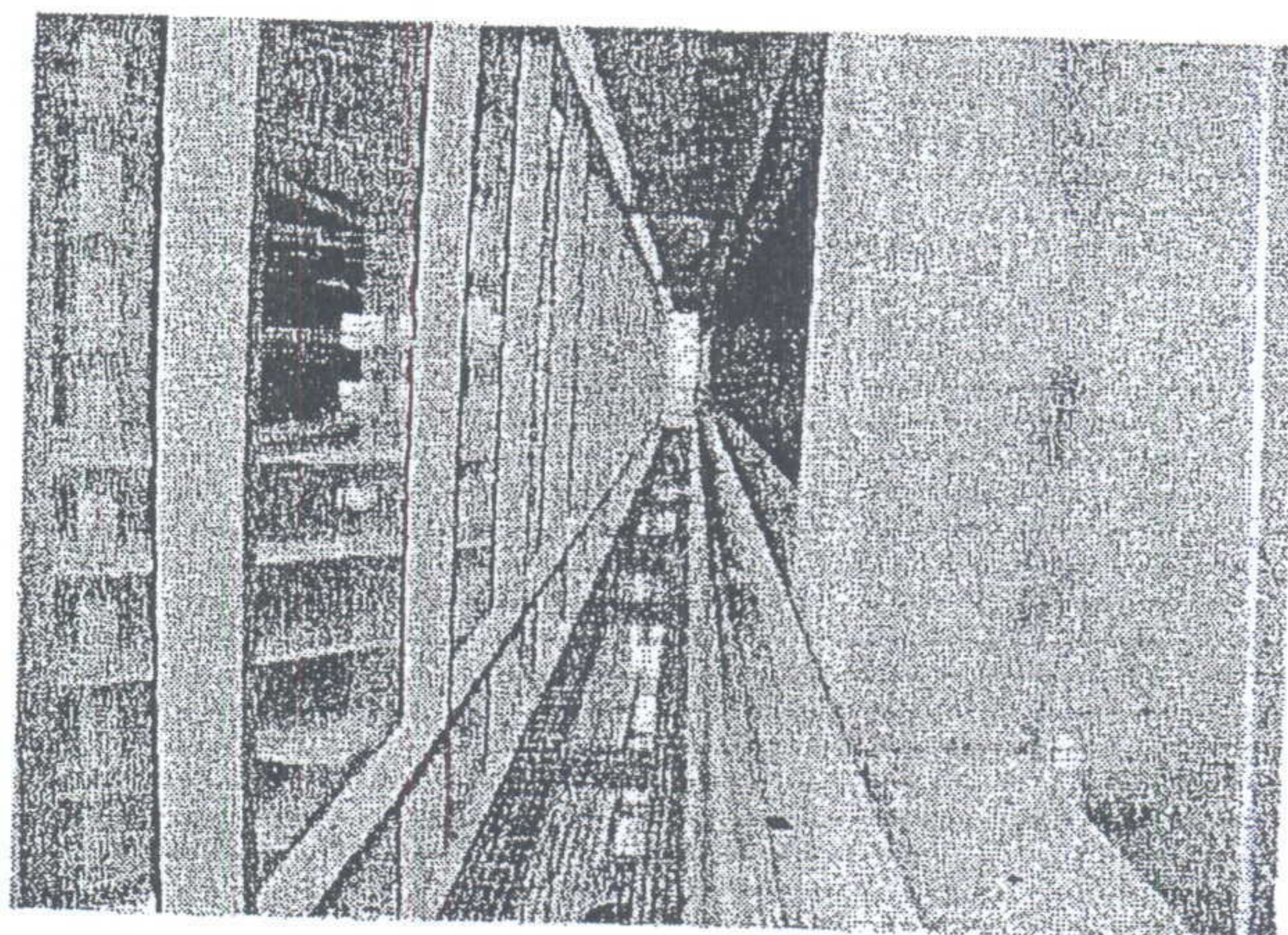
Pic. 13 Reported typical tie at roof level, before solar panels installed. Note plate bolted to parapet wall.



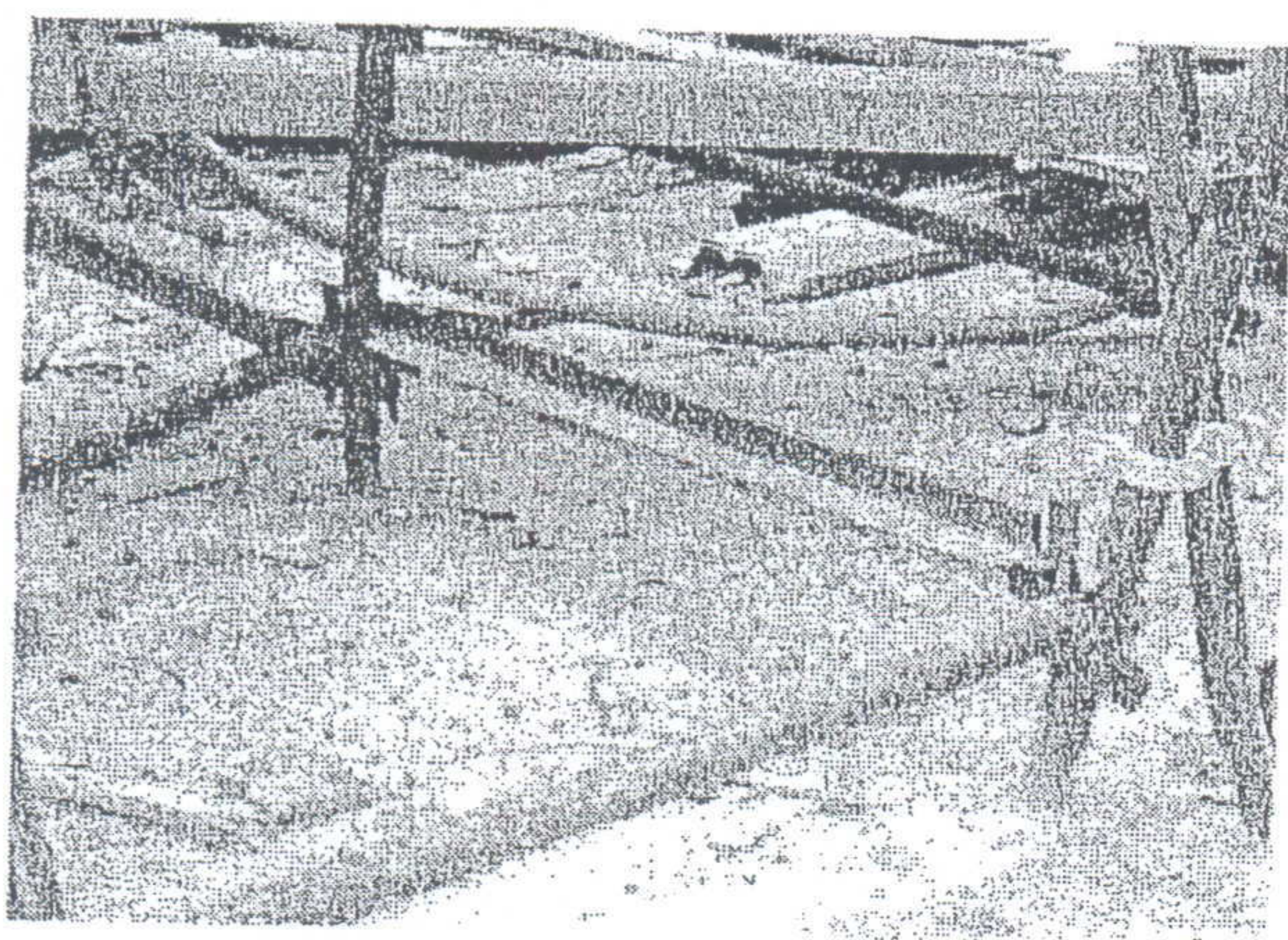
Pic. 14 Reported typical change to tie at roof level, after solar panels installed. Note ties are not bolted to parapet wall.



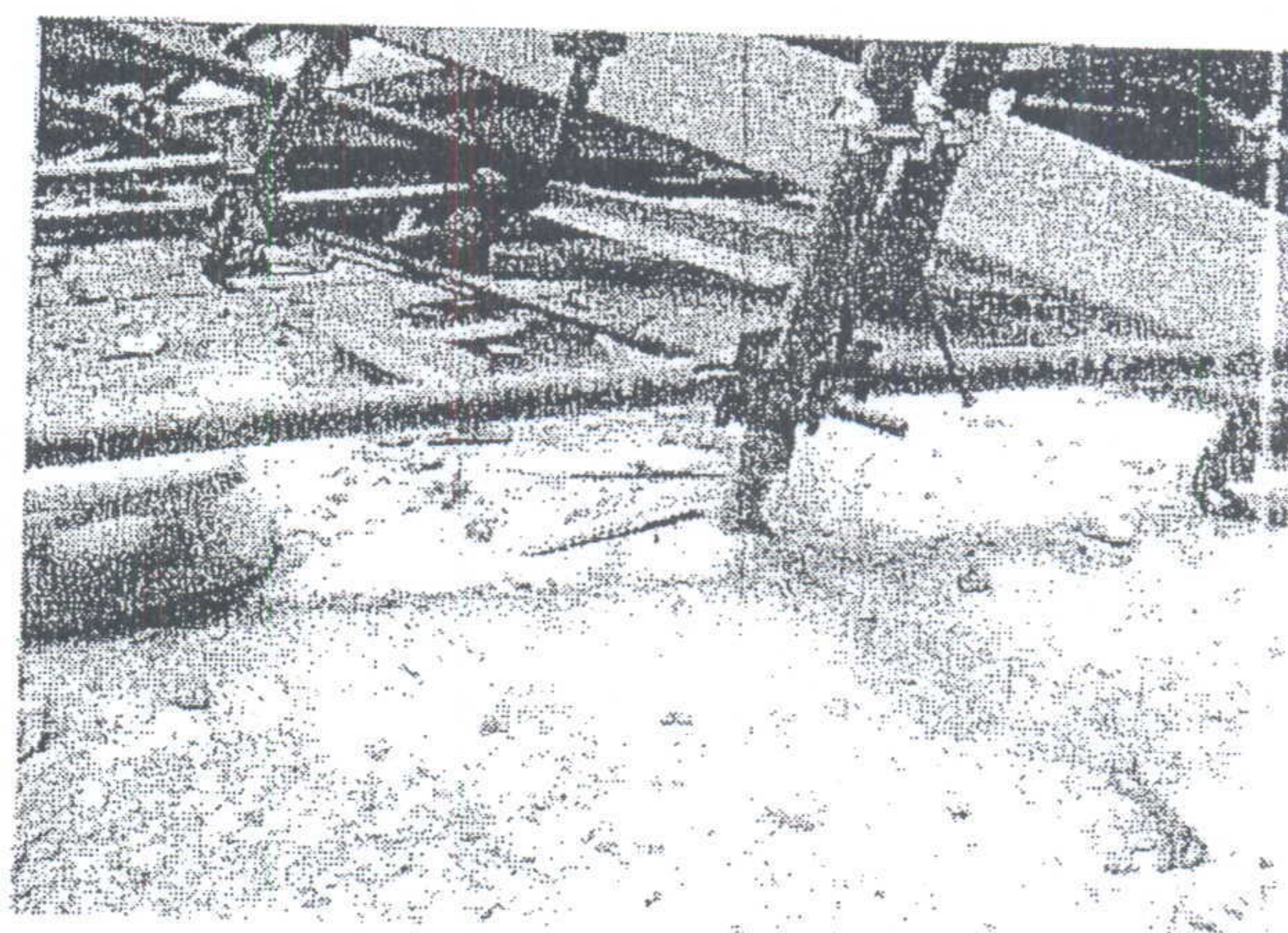
Pic. 15 Typical south east side of floor, after solar panels are installed.



Pic. 16 Typical space between outer face of column and solar panel. Note no sign of tie members.



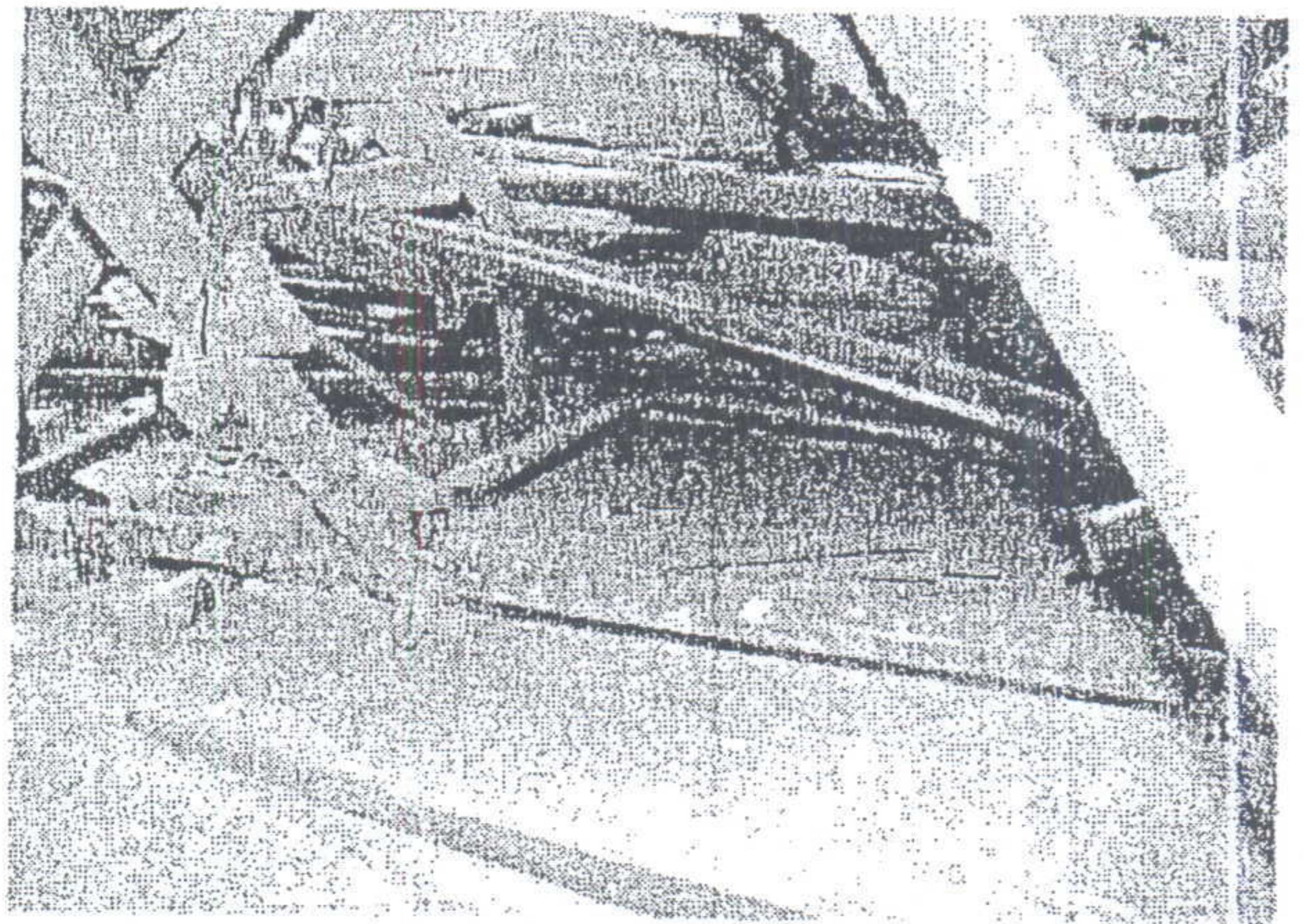
Pic. 17 The south base of collapsed scaffolding. Note lack of base plates or equivalent components.



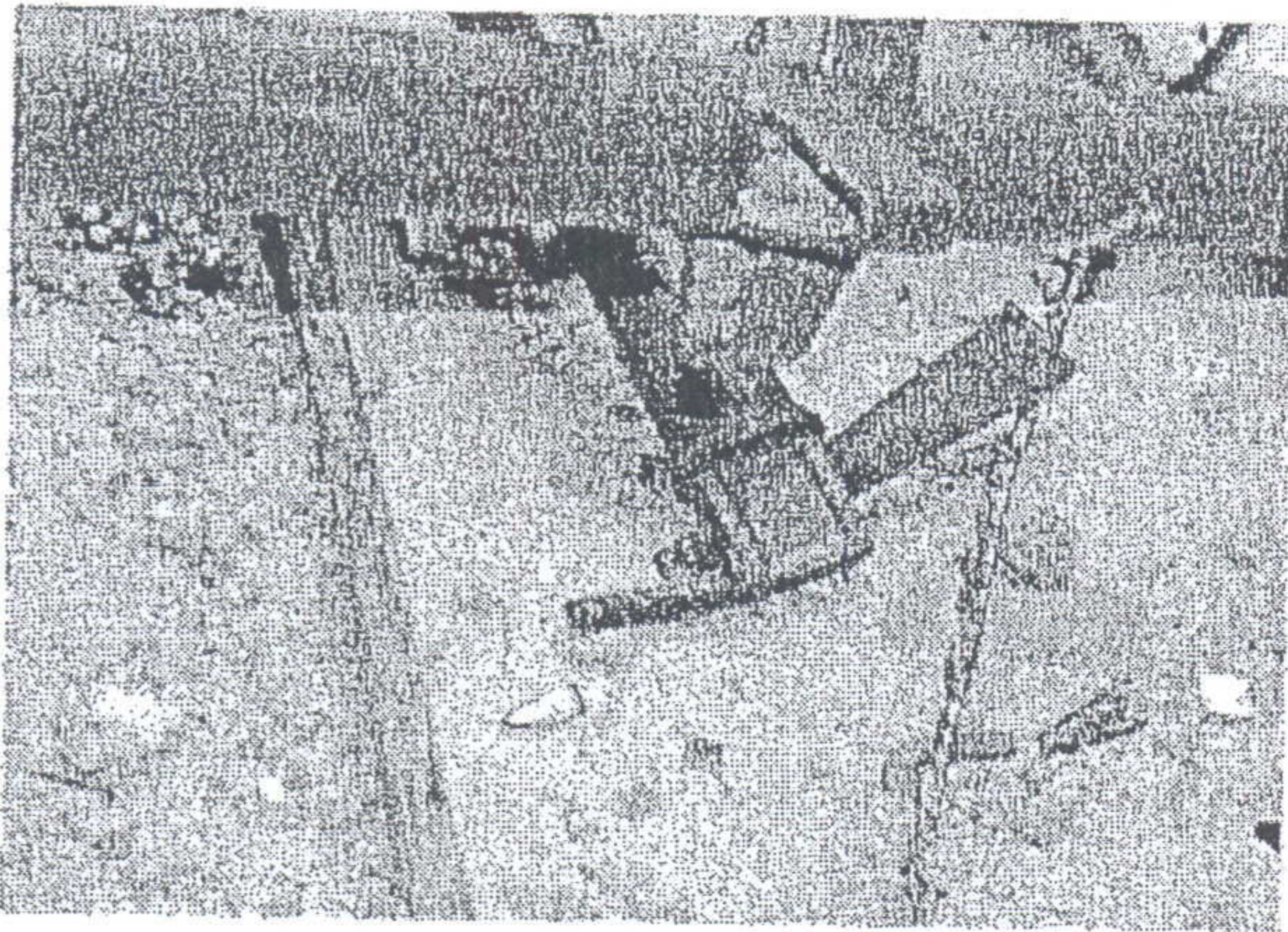
Pic. 18 The base, southern area of collapsed scaffolding. Note lack of base plates.



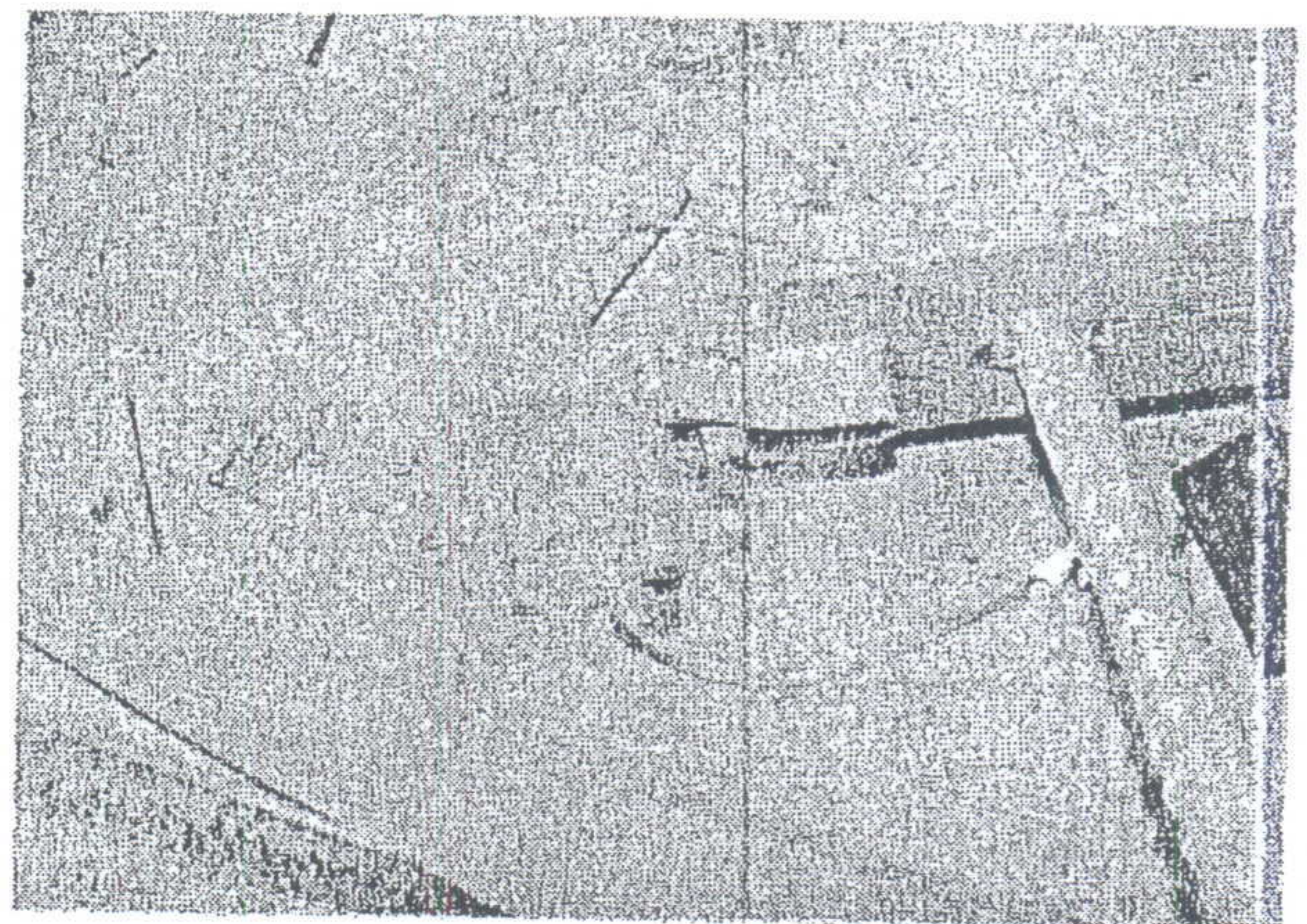
Pic. 19 Typical base of collapsed scaffolding.
Note lack of base plates.



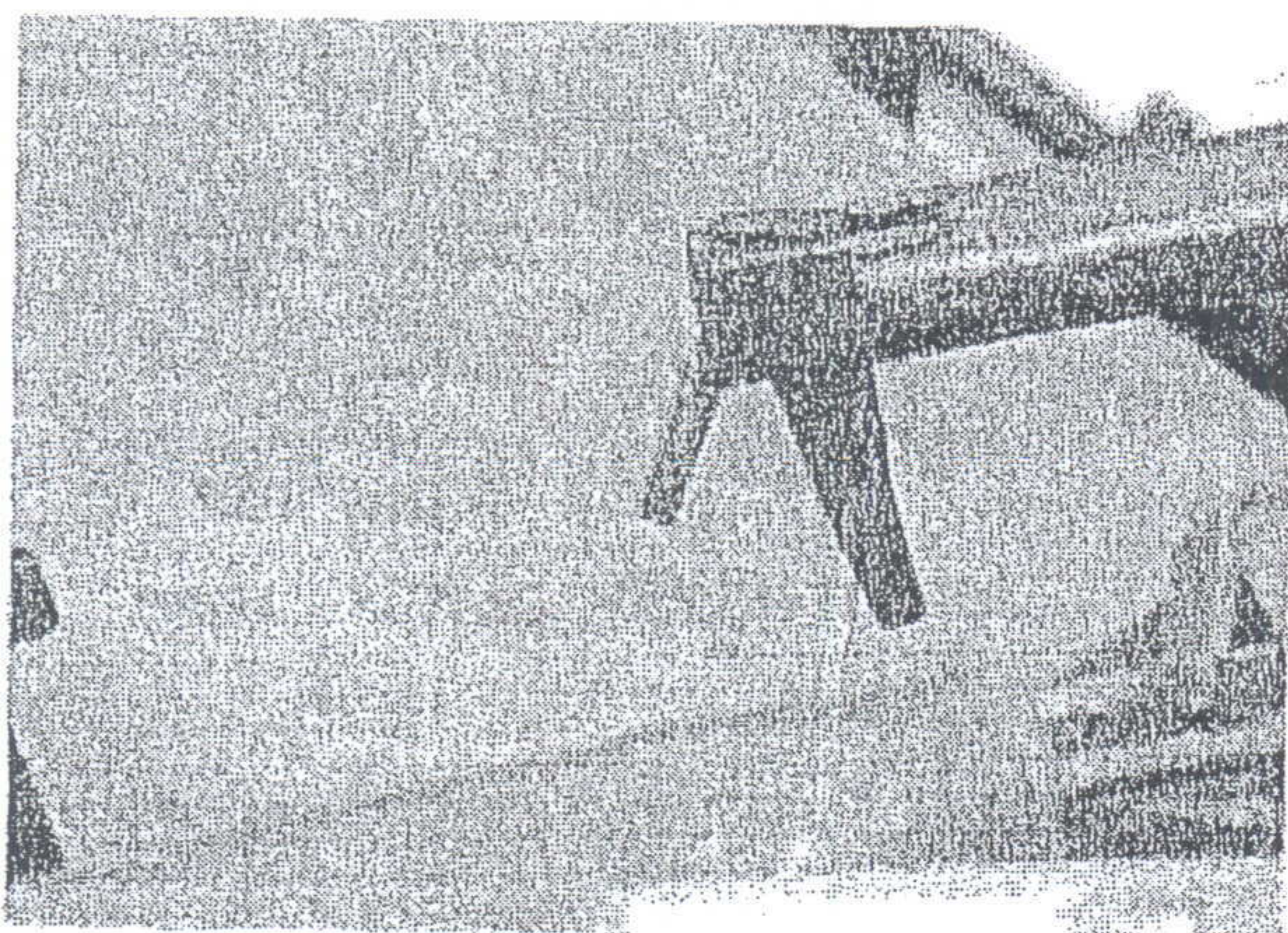
Pic. 20 The base, north section of collapsed scaffolding.
Note lack of base plates or equivalent components.



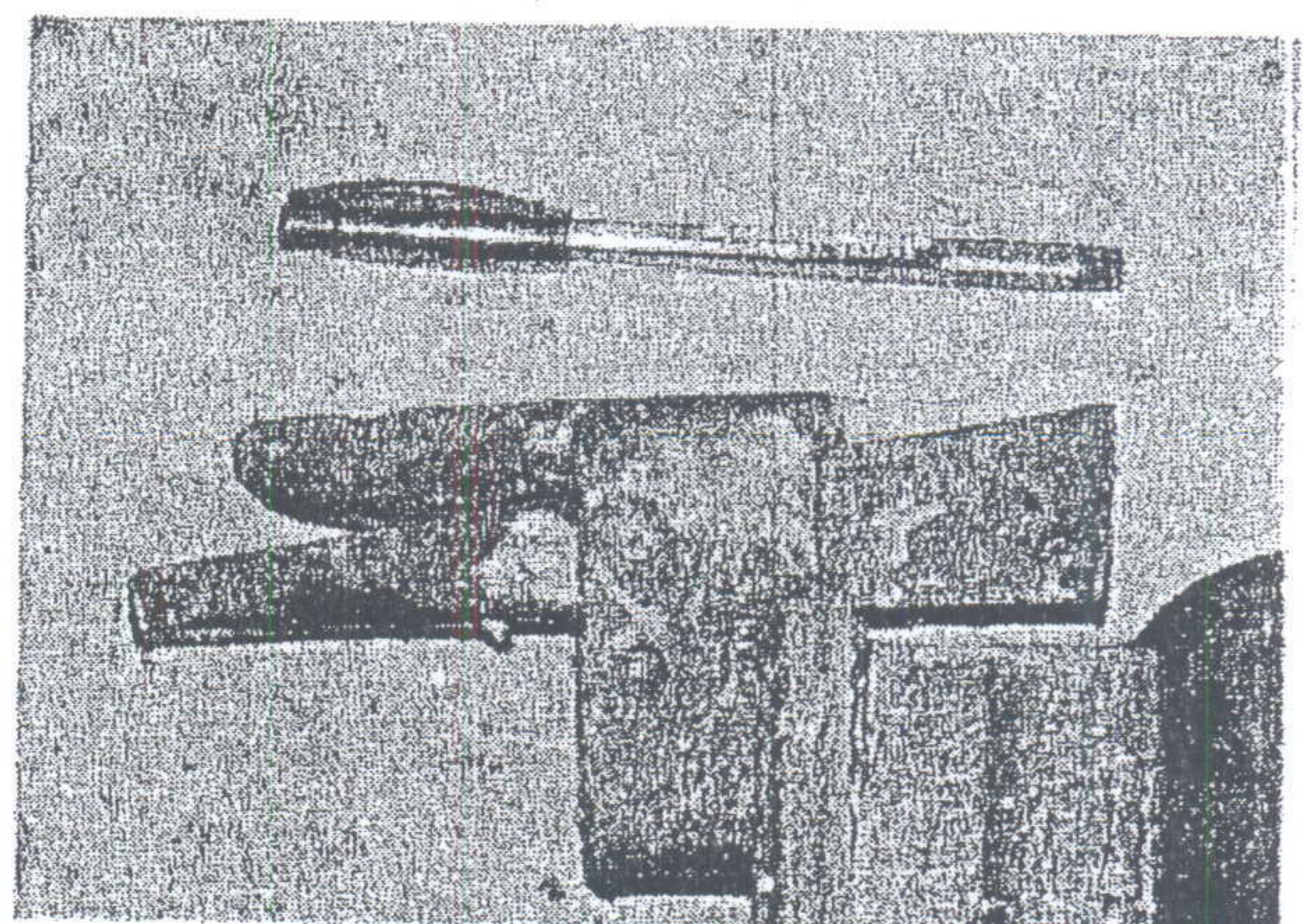
Pic. 21 Modified end connector on ledger of collapsed scaffolding. Note cut steel bar welded to end.



Pic. 22 Modified end connector on hop-up bracket of collapsed scaffolding. Note cut steel bar welded to end.



Pic. 23 Modified end connector on ledger of collapsed scaffolding. Note cut steel bar welded to end.



Pic. 24 Typical connector on transom of collapsed scaffolding.

8.2 Appendix II

Material Testing ~ CARIRI



Caribbean Industrial Research Institute
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Telephone: (868) 662-7161 Telefax: (868) 662-7177
www.cariri.com E-Mail: mail@cariri.com

SERVICE PROJECT REPORT

CLIENT: MINISTRY OF LABOUR AND SMALL AND MICRO ENTERPRISE
DEVELOPMENT
ADDRESS: Riverside Plaza, Besson Street, Port of Spain
PROJECT: Testing of Scaffolding Material – Custom & Excise Building
PROJECT CODE: EC03828936/06
REPORT NO: 3505/06
DATE: September 20, 2006

Page 1 of 17

Amendment report *
(Supersedes report No 3076/06 dated August 17, 2006)

1. INTRODUCTION

On July 12, 2006, scaffolding erected for the construction of the Customs and Excise Building, Richmond Street, Port of Spain collapsed while in service. On July 14, 2006, CARIRI was requested by the client to meet with representatives of the Ministry of Works and Transport (Mr Richard Fulchan) and the Ministry of Labour (Mr Jeffrey Millington) to determine the testing services which can be provided by CARIRI on the investigation being conducted into the collapse of the scaffolding. Mr Marco Nunes of CARIRI visited the site.

At the site Mr Fulchan (MOWT) selected the tests and the samples required for testing. The tests requested were as follows:

1. Visual inspection
2. Dimensional measurements
3. Hardness test
4. Tensile test

Eight (8) samples were selected. Sampling was facilitated by representatives of NH International (Messrs John Dempsey and Martin Richards) through the provision of

* Changes indicated by sidebars in the column.

1. This report relates solely to the specific sample of the product, which has been tested or analyzed by CARIRI as the basis for preparing the report. The report shall be used solely for informing the Client of the results of the test or analysis of that specific sample. It shall not be used for purposes of certification of similar or other products produced by the same manufacturer or the Client or for any other purpose.
2. The report is confidential to the Client and shall not be disclosed by the Client to any person other than professional advisers and responsible officers and employees of the Client who require such disclosure where necessary for the proper performance of their duties and who will individually comply with all obligations of confidentiality imposed on the Client by this provision. Without limiting the generality of the foregoing the report shall not be used or referred to in any advertisement or the marketing of the product.

tools and manpower. NH International also facilitated the transport of two large samples. A list of the samples taken from the site was prepared by Mr Richards of NH International and a copy is presented in Appendix I. Samples were delivered to the CARIRI Laboratory at Macoya on the evening of July 16, 2006 and were assigned CARIRI identification numbers and were stored in designated storage areas.

NH International identification, description and assigned CARIRI identification numbers are as follows:

Table 1
Sample identification

Item	CLIENT Identification	Description given	CARIRI Identification
1	#1 C&E – PK-1 (14-07-2006) – Scaffold pipe	24" length, 1½" dia. Scaffold pipe	T065895
2	#2 C&E – PK-1 (14-07-2006)	36" length, 1½" dia. Scaffold pipe	T065896
3	#3 C&E – PK-1 (14-07-2006)	18" length, 1½" dia. Scaffold pipe	T065897
4	#4 C&E – PK-1 S- pipe (14-07-2006)	24" length, 1½" dia. Scaffold pipe	T065898
5	#5 C&E – PK-1 Horiz. Plank brace (14-07-2006)	6" length, 4"x 2" angle iron brace & pin assembly	T065899
6	#6 C&E – PK-1	2½" length, pin section	T065900
7	#7 C&E – PK-1	8' x 8" x 2" metal scaffold plank	T065901
8	#8 C&E – PK-1	8' x 8" x 2" wooden scaffold plank	T065902

2. APPROACH

The investigation carried out involved the following:

1. *Visual inspection.* The samples were visually inspected and a brief description was made. Photographs were taken to record observations made.
2. *Dimensional measurement of samples.* The samples were measured to determine their dimensions, including, length, width, and thickness among others. Samples T065901 and T065902 (planks) were weighed.

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3. *Hardness test.* A traverse Vickers hardness test profile was performed on the weld of sample T065900. A Zwick Vickers hardness tester type 3202 was used.
4. *Tensile test.* Samples T065897 and T065898 were coupled and tested as a unit to determine the load bearing capacity of the friction joint. A DMG universal testing machine Model Avery No. XT98040 was used.

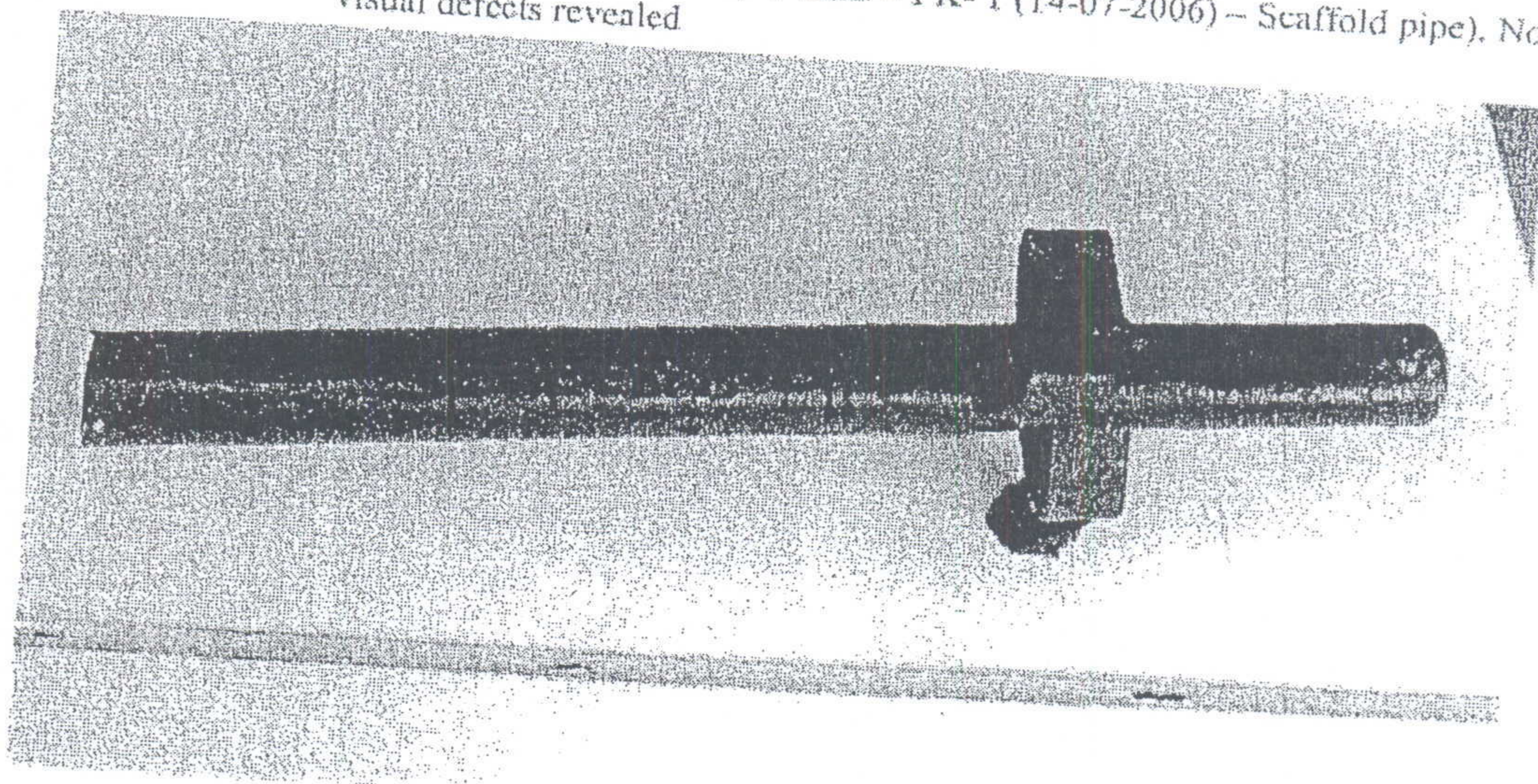
3. RESULTS

3.1 Visual Inspection

A visual inspection was carried on the samples submitted.

The photographic record is presented in Figures 1 to 9.

Figure 1: View of sample T065895 (#1 C&E – PK- 1 (14-07-2006) – Scaffold pipe). No visual defects revealed



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Figure 2: View of sample T065896 (#2 C&E – PK- 1 (14-07-2006). Fractured across length.

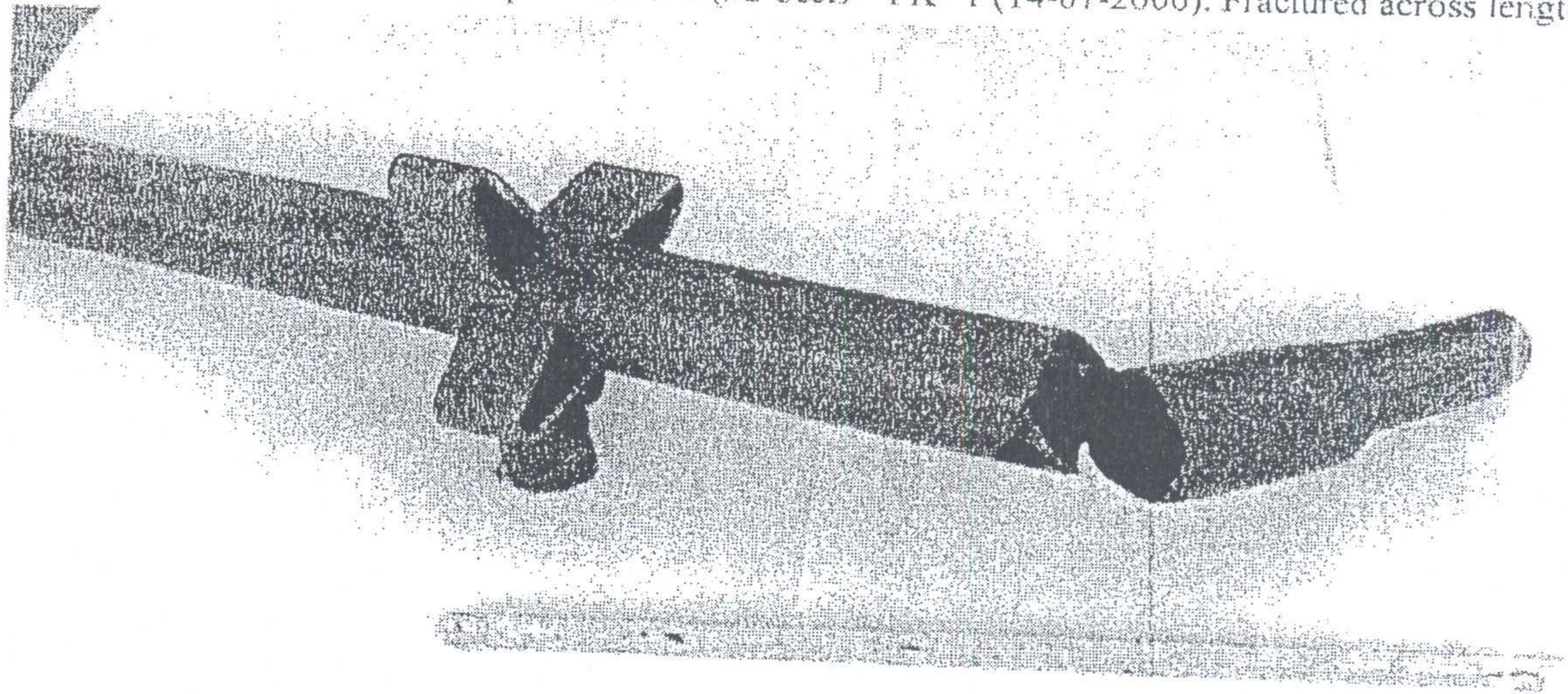
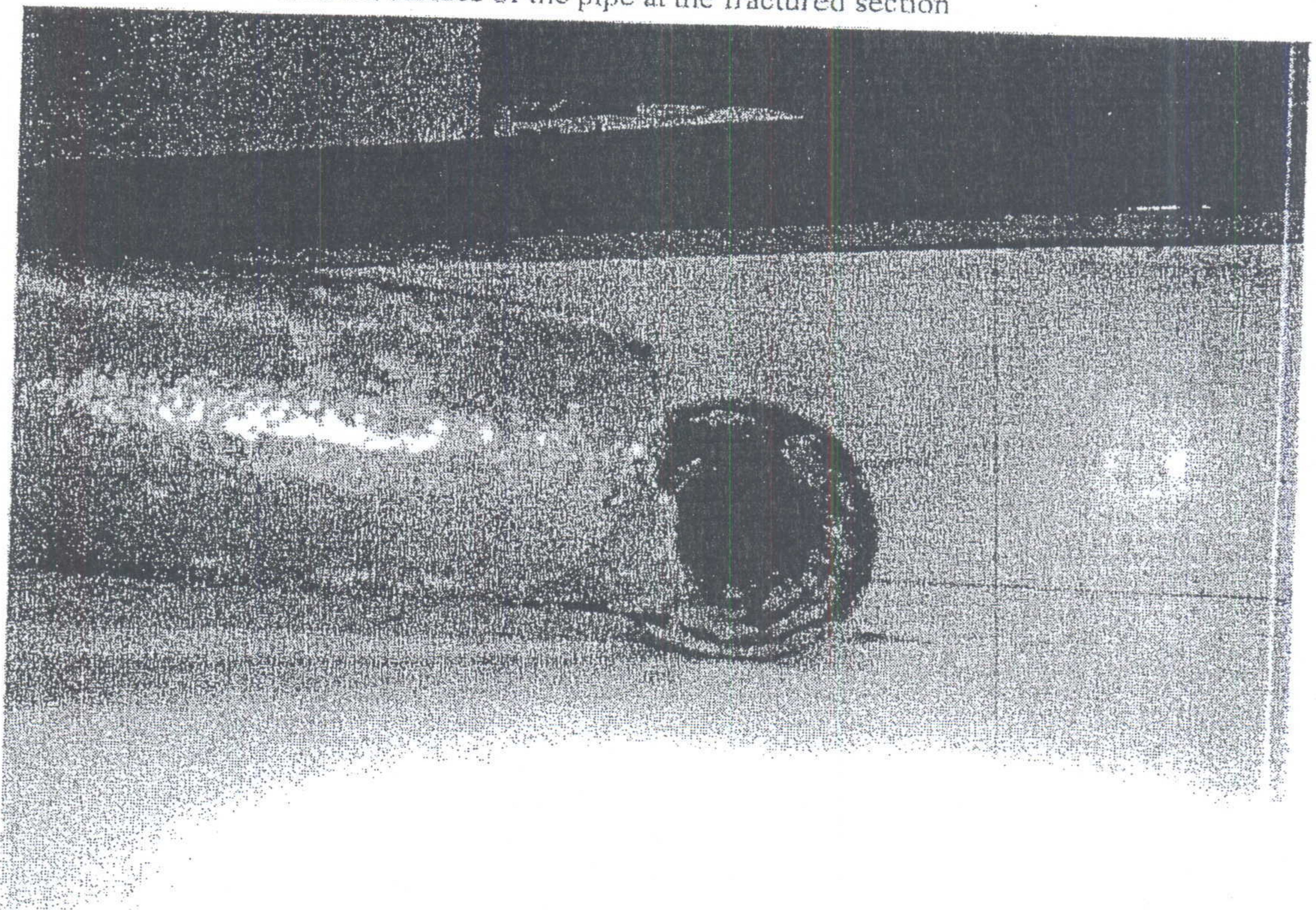


Figure 3: View of sample T065896 (#2 C&E – PK- 1 (14-07-2006), showing the corrosion on the internal surface of the pipe at the fractured section



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Figure 4: View of sample T065896 (#2 C&E – PK- 1 (14-07-2006)), showing (a) a welded and (b) a metallic insert as part of the configuration used during service

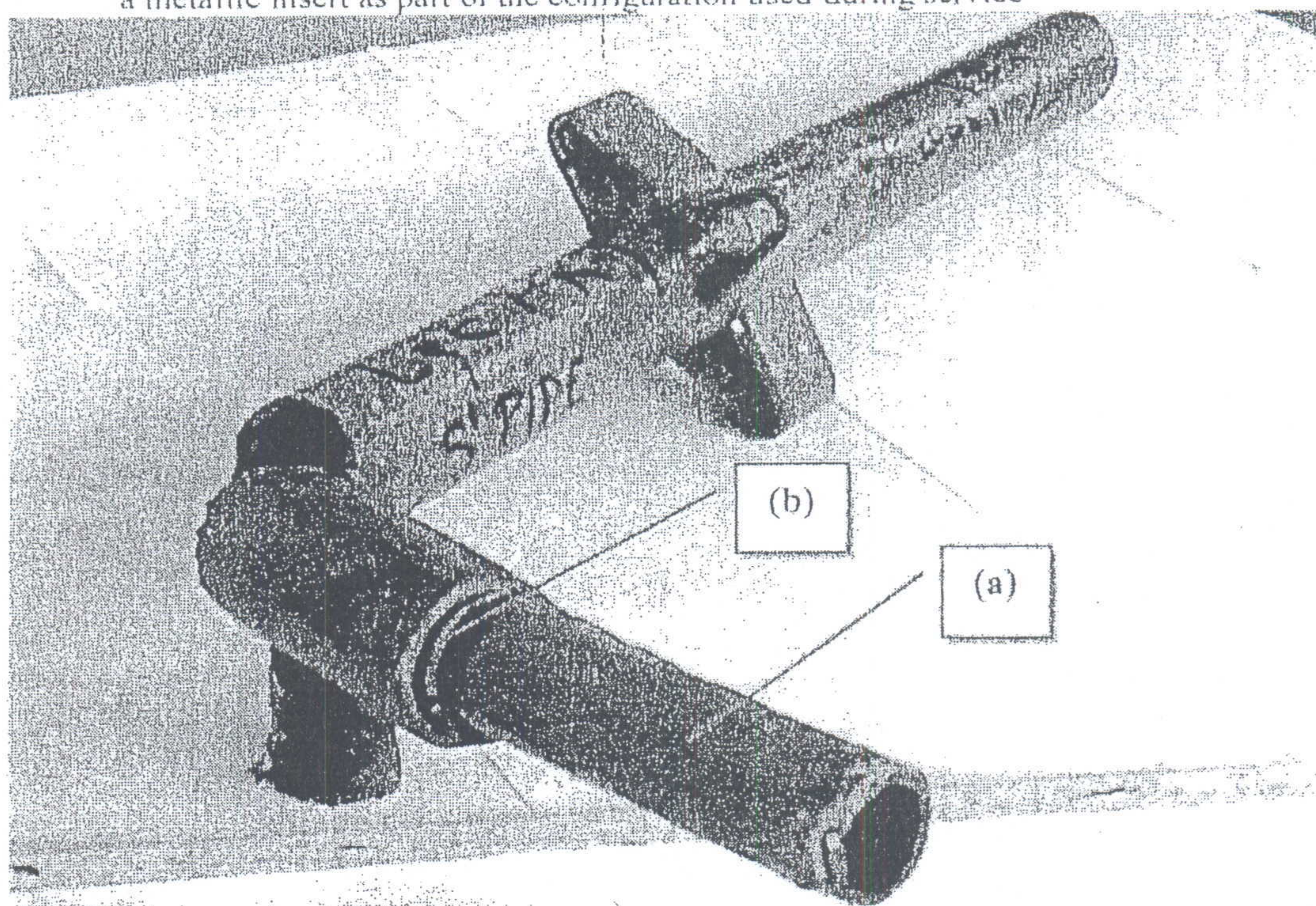
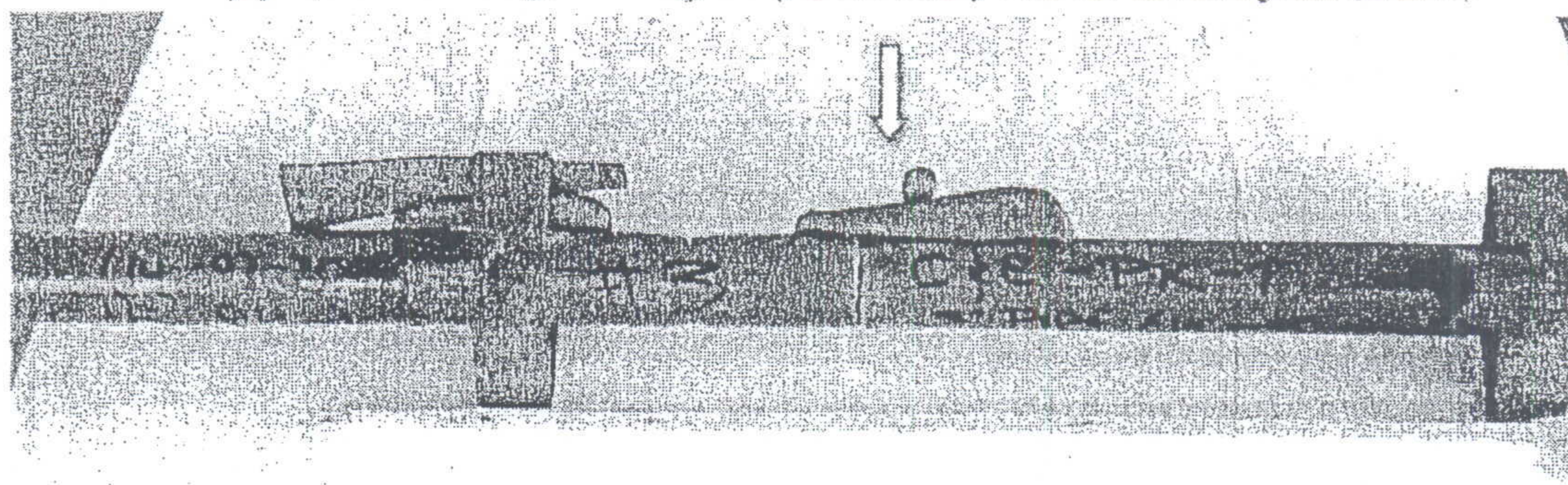


Figure 5: View of samples T065897 (#3 C&E – PK- 1 (14-07-2006)) and T065898 (#4 C&E – PK- 1 S- pipe (14-07-2006)), showing the pin assembly and the friction joint (arrow)



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Figure 6: View of sample T065899 (#5 C&E - PK- 1 Horiz. Plank brace (14-07-2006)), showing the fractured brace.

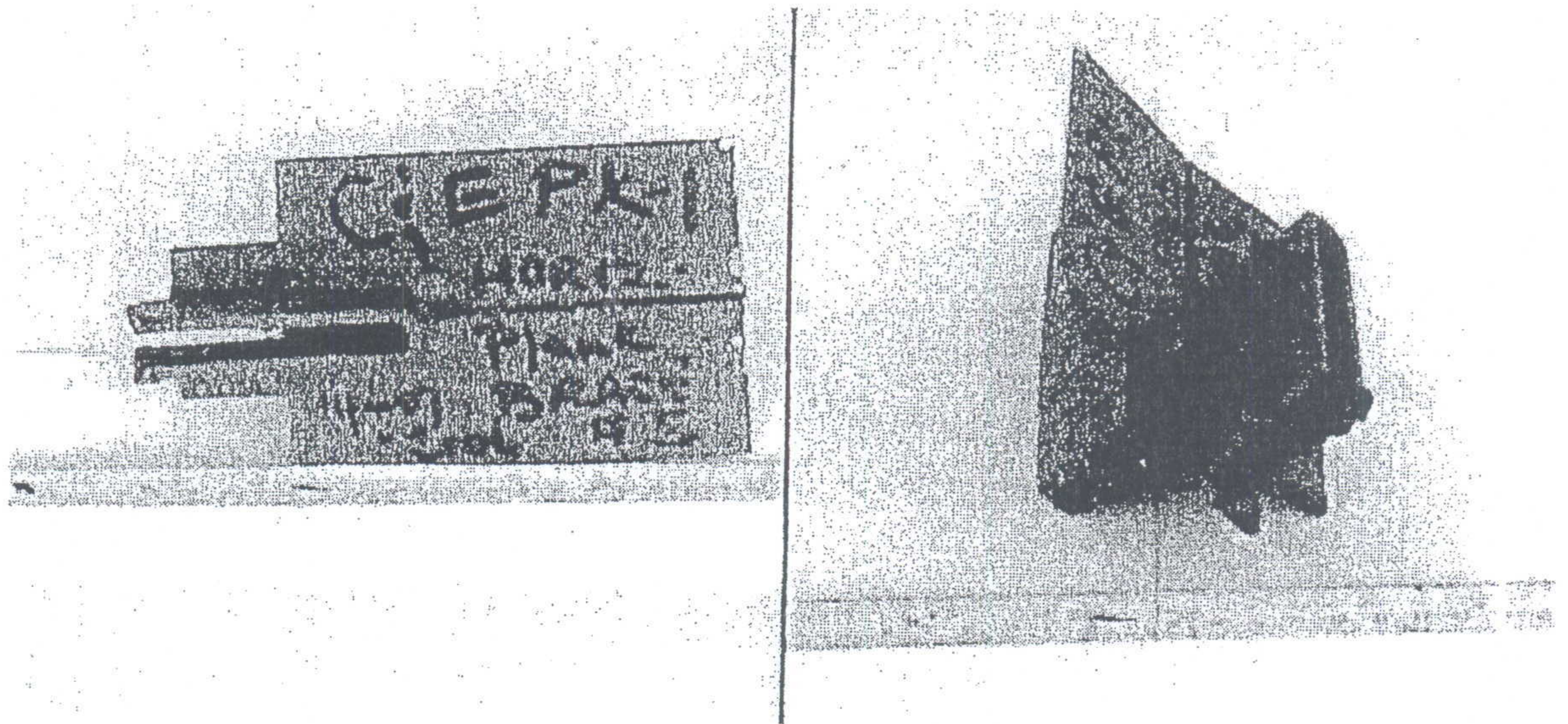
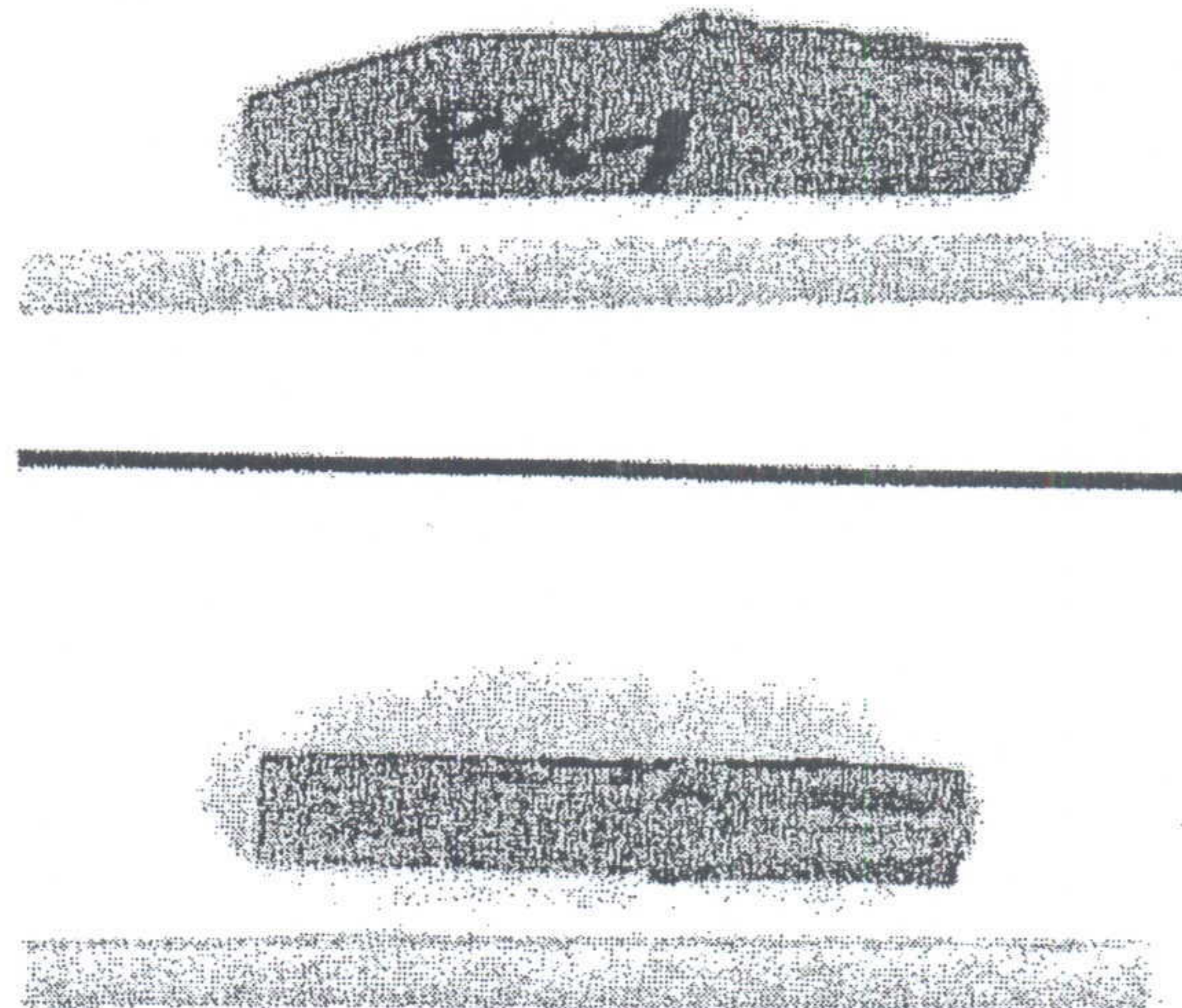
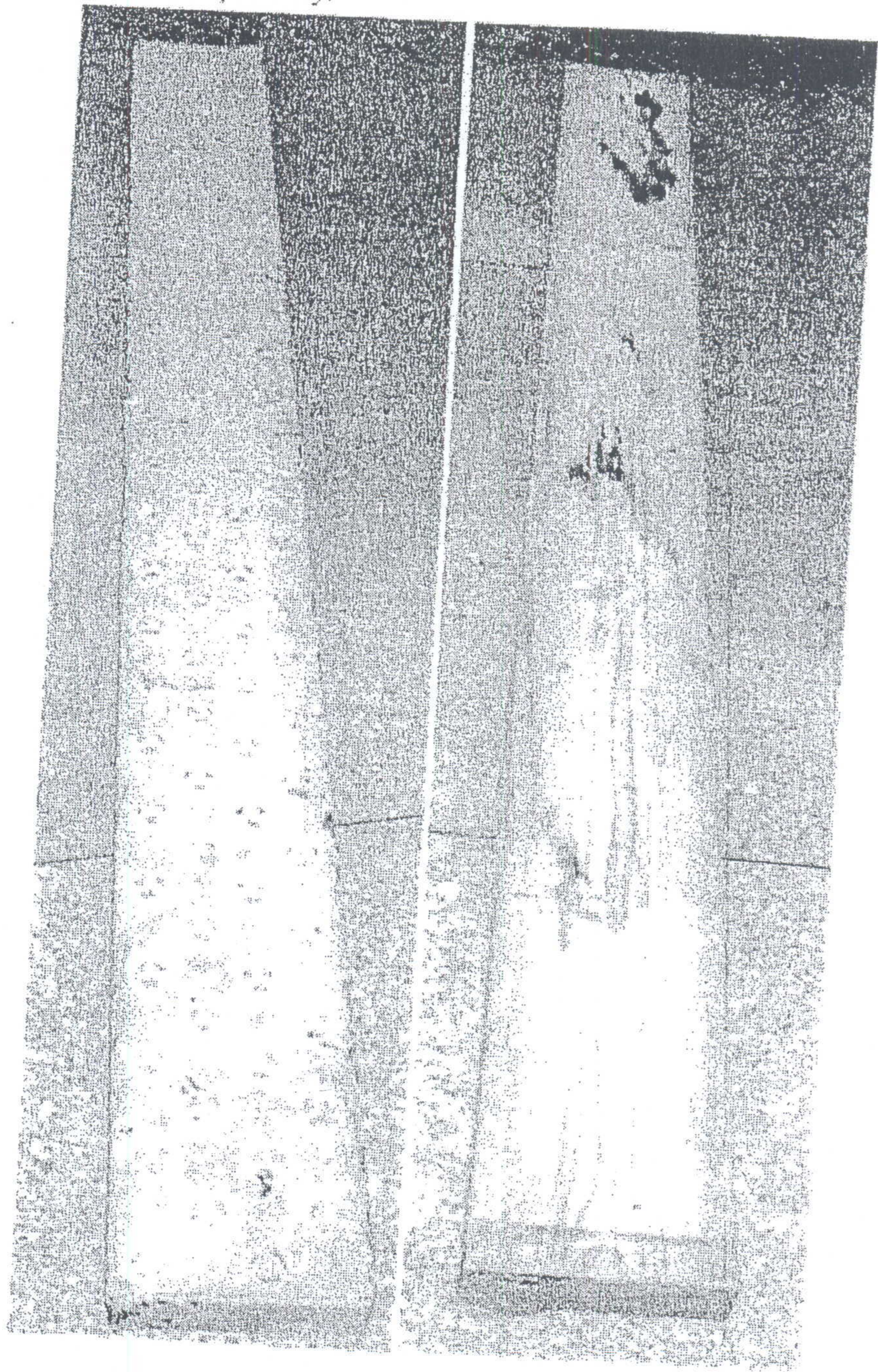


Figure 7: View of sample T065900 (#6 C&E - PK- 1), showing the fractured surface of the matching side of sample T065889.



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Figure 8: View of samples T065901 (left) and T065902 (right) — metal and wooden planks respectively.



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Table 2B
Wall thickness of scaffolding pipe – Sample T065896
(Longitudinal measurements)

Measurement Position	Thickness (mm) $\pm$ 0.01 mm
	T065896
1	1.20
2	3.95
3	3.28
4	3.81
5	3.76
6	3.33
Average	3.22

For Sample T065896, the six (6) points where measurements were taken are shown in Figure 9, Appendix II.

Dimensional and weight measurements were carried on the two plank samples, Samples T065901 and T065902. Results are presented in Table 3.

Table 3
Dimension and weight measurements

Sample ID	Thickness (cm) $\pm$ 0.1 cm	
Dimension	T065901	T065902
Length	242.0	241.7
Width	22.8	21.4
Height	6.5	5.7
Weight (kg) $\pm$ 0.02 kg	15.86	13.98

Dimensions measured are shown in Figure 10, Appendix II.

3.2 Hardness test

A Vickers hardness test profile was performed across the weld of Sample T065900. The results obtained are presented in Table 4. A macrograph of the sample tested is shown in Figure 11, Appendix II.

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Table 4
Vickers Hardness Test Traverse (HV₁₀) (Sample T065900)

	Weld		HAZ	Base metal					HAZ	Weld
Point	1	2	3	4	5	6	7	8	9	10
Hardness Vickers	263	271	332	162	153	171	135	201	305	264

HAZ - Heat affected zone

3.3 Tensile test

Samples T065897 and T065898 were coupled as a unit and tested twice to determine the load bearing capacity of the friction joint. The results are presented in Table 5. A photograph showing the arrangement used for the test is presented in Figure 12, Appendix II.

Table 5
Tensile test results
Coupled Samples T065897 and T065898

Test No.	Load (kN)
1	2.98
2	3.12
Average	3.05

4. DISCUSSION

Based on the investigation conducted, the following are noted:

- The scaffolding pipe sample, Sample T065896 (#2 C&E - PK- 1 (14-07-2006)), shows severe corrosion on the internal surface of the pipe at the fractured section. See Figures 2, 3 and 4. The pipe has a welded patch and a metallic insert located between the main pipe and the extension. See Figure 4.
- The average wall thickness obtained in Sample T065895 is 4.09 mm. This sample did not show any signs of corrosion (internal and external) and was taken as a reference for assessing wall thickness. The fractured pipe, Sample T065896 (#2 C&E - PK- 1 (14-07-2006)) has an average thickness of 3.22

The word "not" was inadvertently omitted in report 3076/06. It is included in this report.

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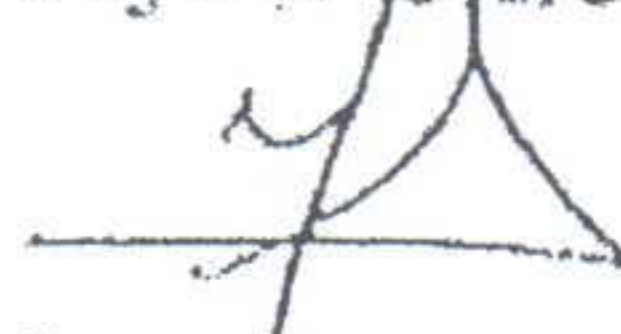
area, which represents an approximate 70% reduction in wall thickness in reference to sample T065895.

- Sample T065899¹ (#5 C&E – PK- 1 Horiz. Plank brace (14-07-2006)) is a broken brace that contained a welded joint of rolled steel and cast metal. The weld was made by arc welding. Failure occurred at the weld. The hardness test shows a significant difference in hardness between the weld, heat affected zone (HAZ), and base metal, which indicates that a high level of stress was introduced at this location through the welding operation.

Technician(s):

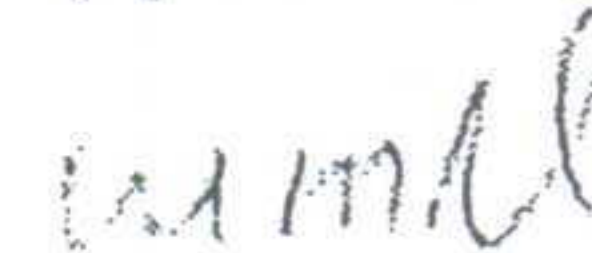
Rishi Deonarine

Project Chief:



Marco Nunes
Materials Engineer

Approved by:



Kamral Mohammed
Laboratory Manager
Industrial Materials Unit

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Appendix I

Copy of list of samples removed from site

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Date: 14 July 2006

Material Removed From Accident Site PK-1
Customs & Excise Building, Ground Floor, Grid lines 1 & 3
S & N.

1 → 24" length, 1 1/2" dia, Scaffold pipe

2 → 36" " " " "

3 → 18" " " "

4 → 24" length, 1 1/2" dia. " "

5 → 6" length; 4" x 2" Angle Iron Brace & Pin Assembly

6 → 2 1/2" length; pin section

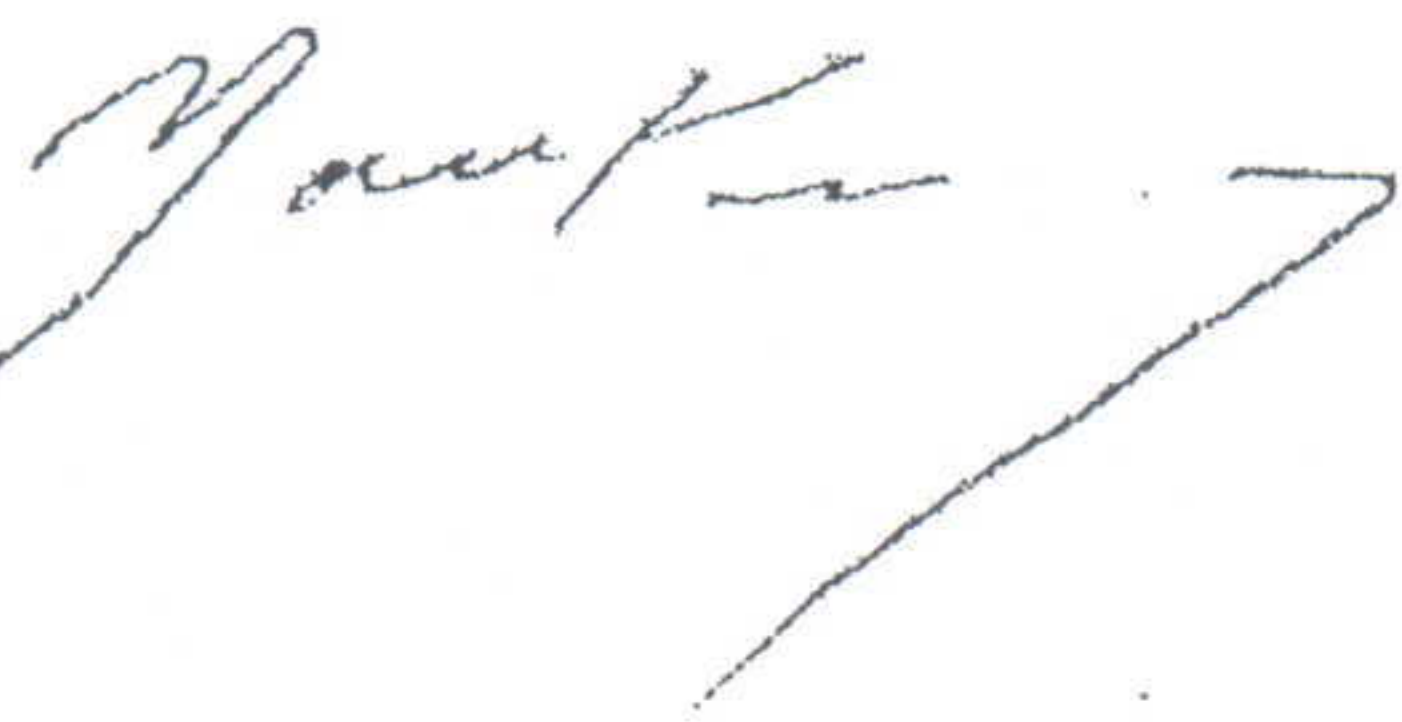
7 → 8' x 8" x 2" Metal Scaffold Plank

8 → 8' x 8" x 2" Wooden Scaffold Plank

Logged by

Martin Richards, TA PM

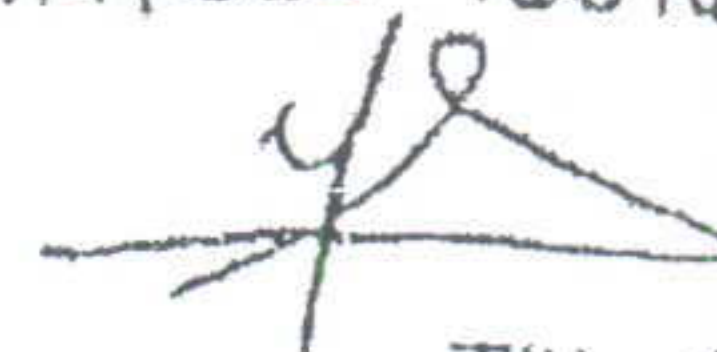
John Dempsey NHIC



RICHARD FULCHAN MOWT

Pilot SLM

MARCO NUNES



JUL 14.06

Appendix II

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Figure 9

Overview of samples T065896 showing where the wall thickness was measured (points 1 to 6) in reference to the fractured side.

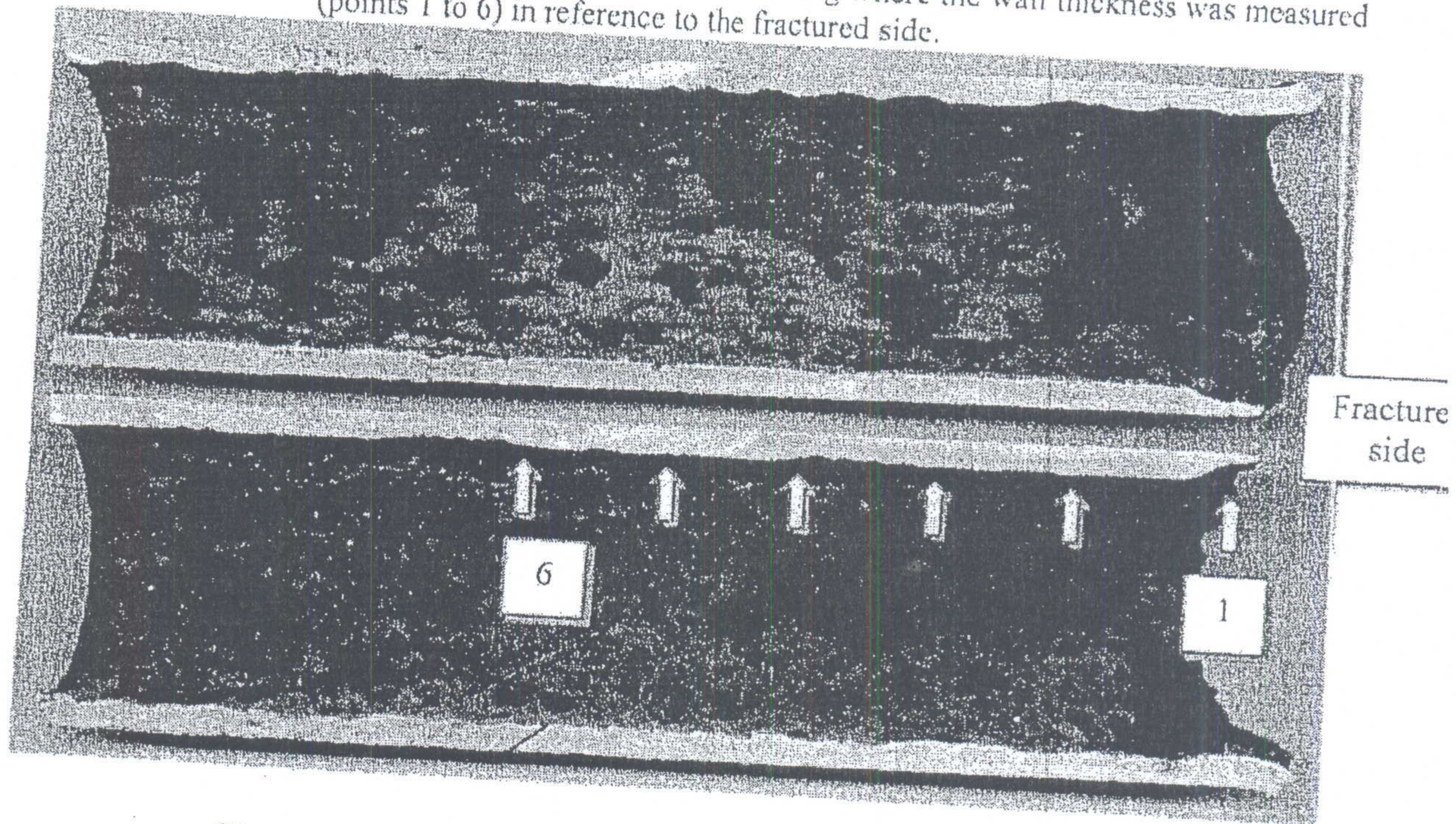
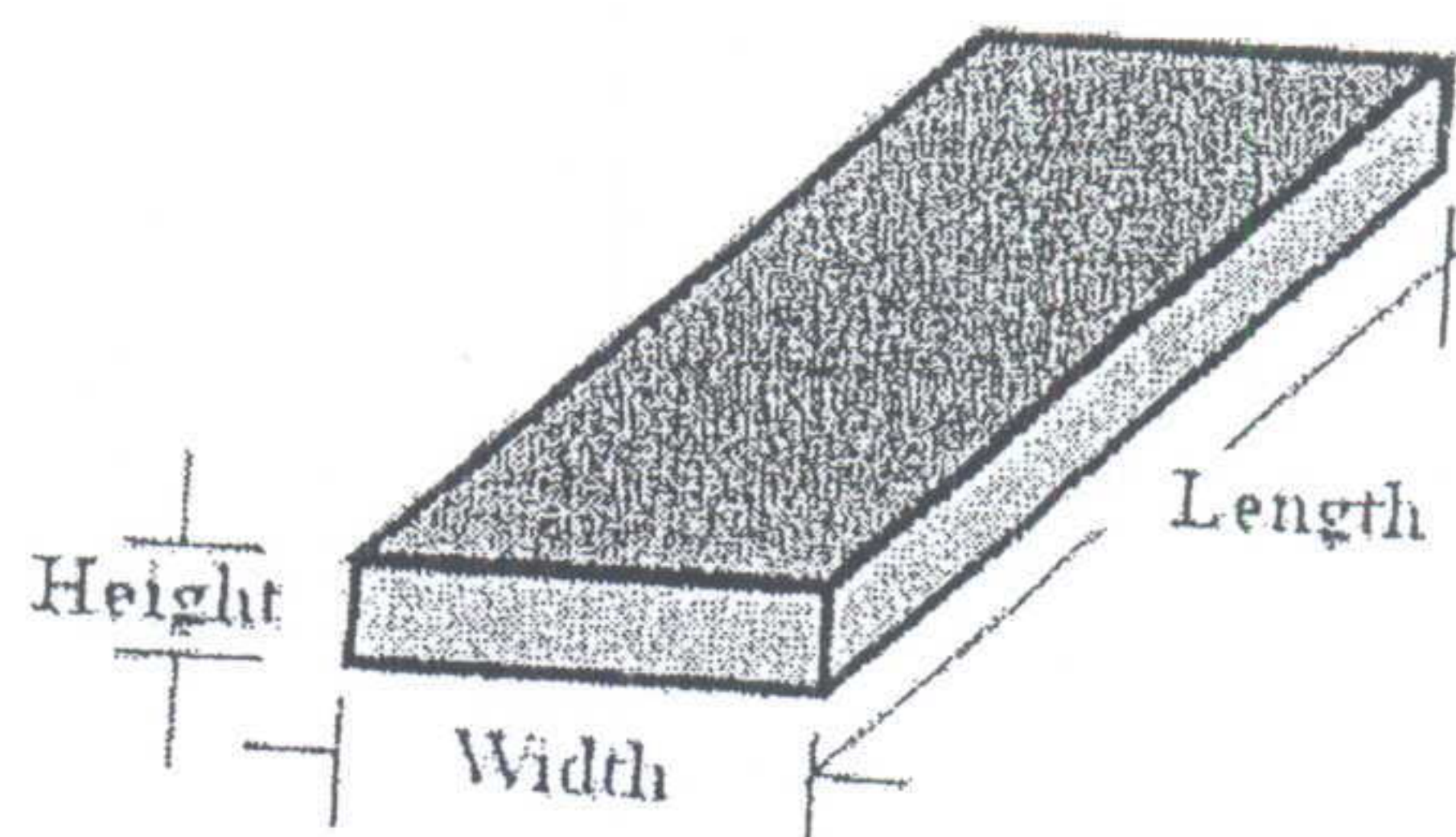
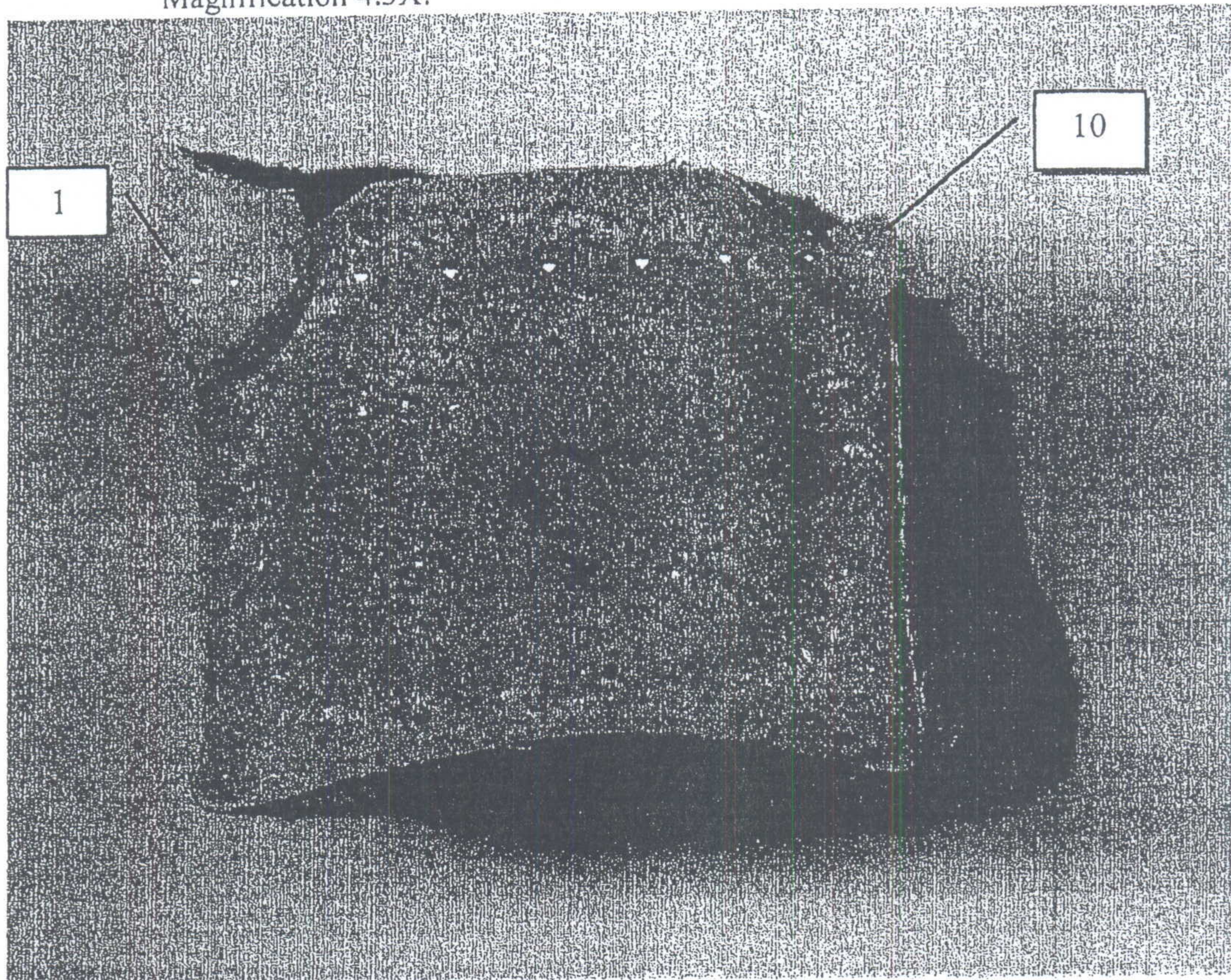


Figure 10 Sketch showing the dimensions measured in both planks



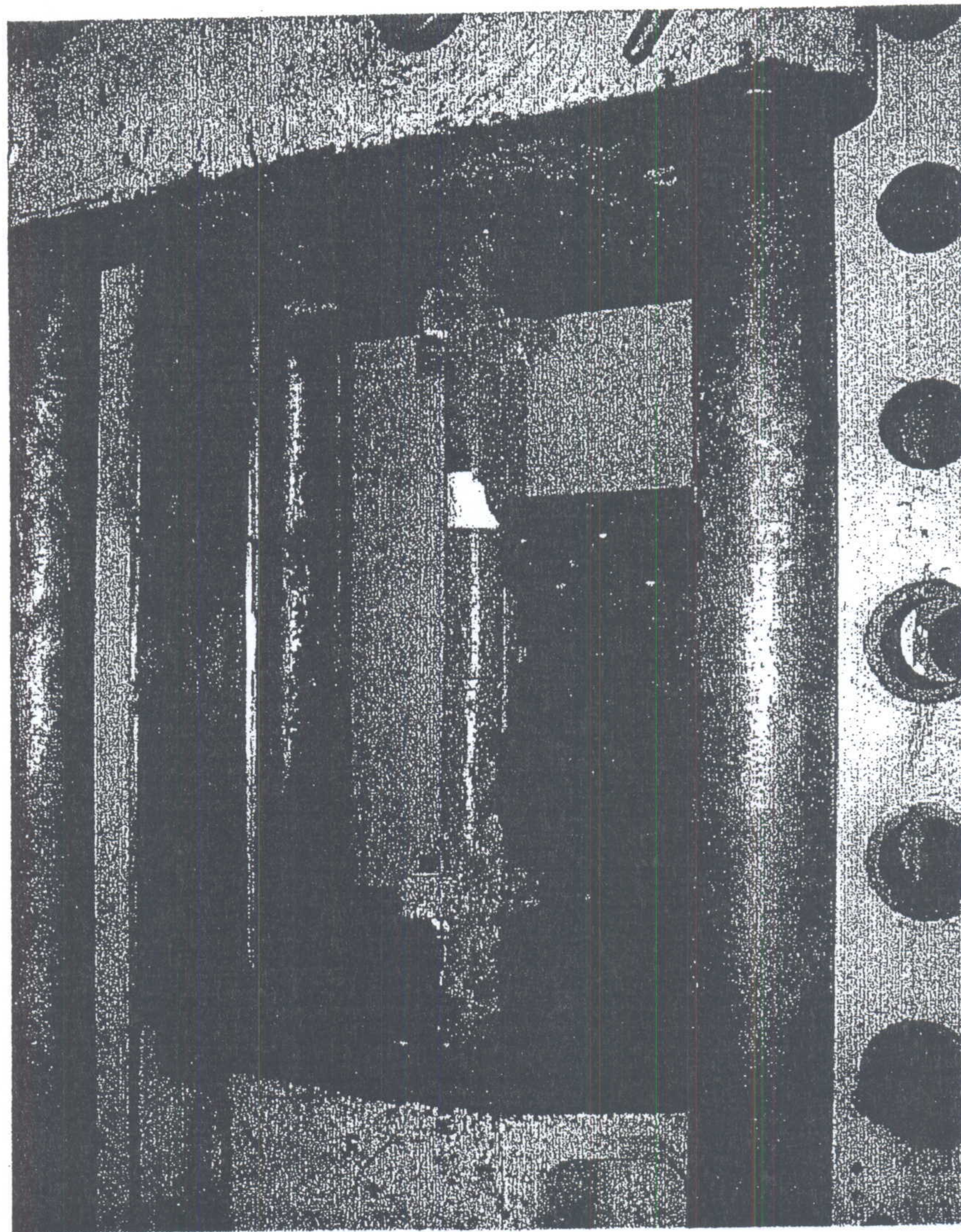
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Figure 11 Macrograph of sample T065900 showing the indentations from the hardness test. Magnification 4.3X.



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Figure 12 Tensile test of friction joint



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8.3 Appendix III

BS 1139 : PART 5 : 1990

Metal Scaffolding