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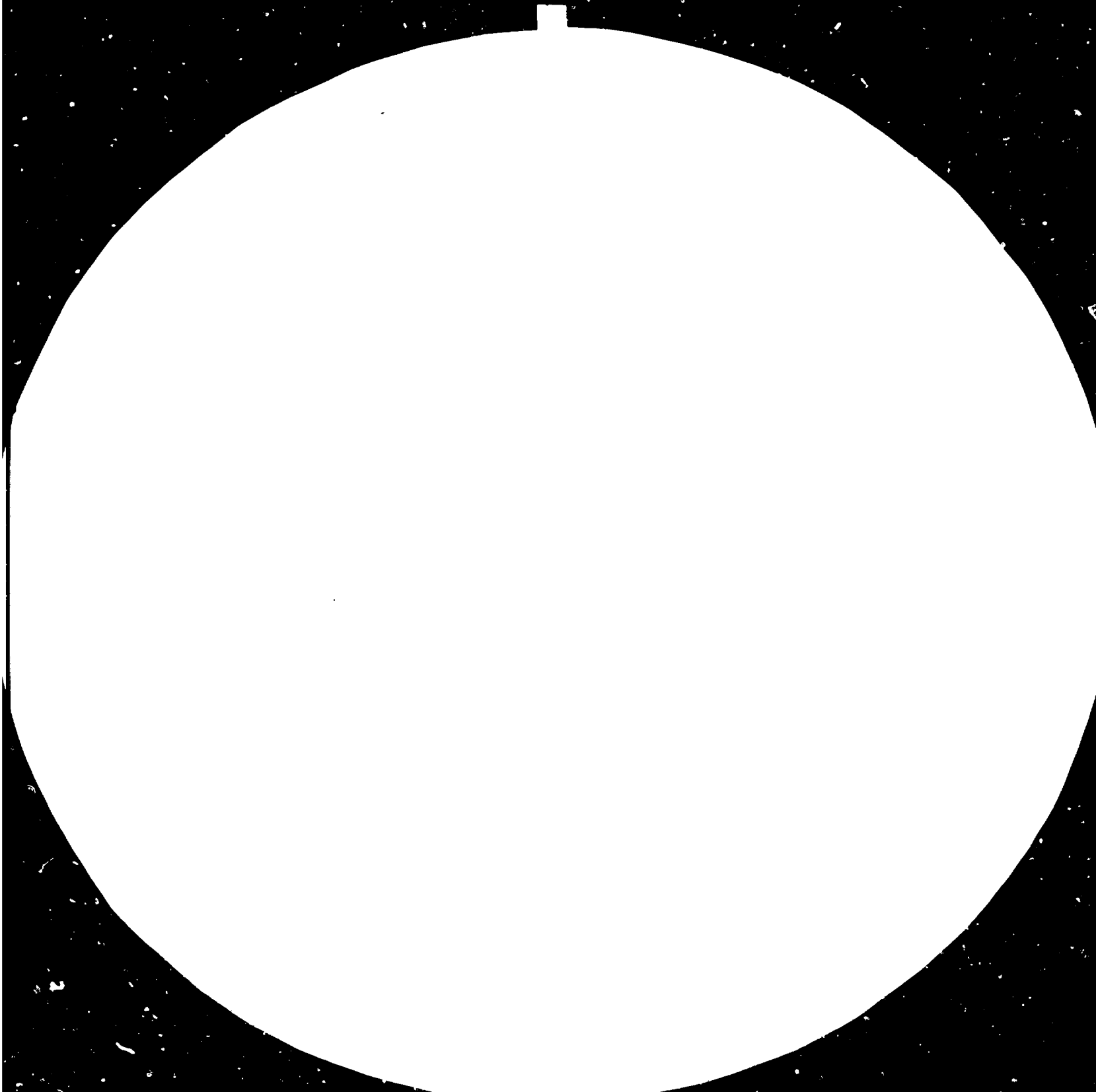
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RESEARCH AND DEVELOPMENT CENTER
FOR LIGHT BUILDING MATERIALS

DP/CPR/82/013

PEOPLE'S REPUBLIC OF CHINA.

Technical report: Light building materials and
structural systems in housing *

Prepared for the Government of the People's Republic of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of William W.L. Chan (U.K.)
adviser on building materials and structures

United Nations Industrial Development Organization
Vienna

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I. INTRODUCTION

The purpose of the one month mission to Beijing, Suzhou, Wuxi and Hangzhou, China, entitled "Structural systems utilizing light building materials" (DP/CPR/S2/O13), a United Nations Development Programme project with United Nations Industrial Development Organisation as executing agency, was for the expert in collaboration with his Chinese counterparts, to familiarize himself with conditions and problems of present and future production of building materials and their use in lightweight house-building systems; to give information on current practice of similar materials and systems abroad through literature, slides and films; to give advice on methods of improving their efficient use particularly in the design of appropriate structural systems; and to make recommendations for the organisation, policy and technical staffing and equipment for and projects to be undertaken by the Centre for Research and Development of Light Building Materials which was being established in Hangzhou.

The expert was attached to the Ministry of Building Materials Industry. The mission was carried out in the month commencing 15 August 1983.

The expert acknowledges the excellent collaboration and kindness given by his Chinese counterparts, especially Mr Qu Tongxin of the Ministry of Building Materials Industry and Mr Mao Wenjie of the Centre for Research and Development of Light Building Materials, Hangzhou.

II. SUMMARY

A mission to Beijing, Suzhou, Wuxi and Hangzhou, China, entitled 'Structural systems utilizing light building materials' (DP/CFR/82/013), a UNDP project with UNIDO as executing agency, was carried out in the month commencing 15 August 1983.

The expert visited factories producing bricks, tiles, aerated concrete blocks and slabs, concrete large panel walls and floors, rock-wool slabs, gypsum board, cold rolled steel framing and glass fibre; building sites mostly of 6 storey blocks of 35m² to 45m² housing units; and gave lectures illustrated by slides, films and literature on building systems and materials in U.K. and Europe.

In the present and future intensive housing construction programme, demand exceeds supply for all building materials. Research and development are aimed at new lightweight materials, reducing consumption of clay (to minimise loss of agricultural land) and maximising the use of industrial waste as raw material.

The expert recommended that in the short term, bricks should have perforations to save clay; wall external faces should be self-finished in brick or concrete without the use of rendering; or paint; reinforced concrete walls and columns should be simplified; and that in the longer term, lighter roofs of concrete tiles or plastic coated profiled steel supported by cold-rolled steel trusses should be developed; loadbearing 'no-fines' concrete and non-loadbearing plastic coated profiled sheeting wall systems should be used; lightweight cold-formed steel and gypsum board building systems should be developed; fire precautions in building design should receive greater attention; and the Centre for Research and Development of Light Building Materials should have facilities for the construction and testing of prototype whole buildings.

III. APPRAISAL

A. Housing demand

China is undertaking a long term housing development programme, as part of the plan to raise the people's standard of living and to relieve the acute housing shortage and overcrowding, particularly in the major cities. The current national housing programme of major cities is some 100M m² per year, with Beijing 6M m² per year.

B. Housing form

Most housing is in form of long blocks six storeys high, the maximum height for which lifts are not required or provided. In Beijing, blocks up to 18 storeys can often be seen, in which lifts are provided. Most housing units are in the range of 35 to 45m² each, with 2 bedrooms, bathroom, kitchen and a small entrance hallway serving as living and dining areas.

C. Building materials

The expert visited factories producing bricks and tiles, aerated concrete or flyash/lime blocks and reinforced slabs, hollow concrete blocks, prestressed hollow core slabs, large panel wall and floor elements, stairs, beams and hollow columns, roofing felt, rockwool insulation slabs, gypsum board, cold rolled steel stud framing, and glass fibre (see Chapter V).

Although demand exceeds supply for all building materials, the shortage of clay for making bricks and tiles, and the loss of agricultural land from clay extraction, are causing concern. Thus investment in research and development of materials and building design is particularly directed towards means of reducing to a minimum the use of clay.

More generally, intense efforts are being made to develop lightweight building materials to obtain the maximum volume of building construction at the least consumption of raw materials and energy. Special priority is given to the use of a wide variety of organic and inorganic industrial waste and by-products as raw materials.

D. Building systems

Housing construction in the cities and sites visited consists of:

Brick loadbearing walls and cast in place or precast floor and roof slabs; or

Reinforced concrete precast frame with infill brick, block or large panel walls and precast hollow floors; or

Large panel concrete loadbearing walls and precast hollow floor and roof slabs; or

Aerated flyash/lime autoclaved loadbearing blocks with precast hollow floor and roof slabs.

Effort is being directed towards the development of very lightweight buildings; in addition to reduced materials consumption, they reduce earthquake-induced loads which occur in seismic areas in many provinces in China. Keen interest was shown in the expert's own development of a lightweight building system using a cold-rolled steel stud structural frame with thin board materials for internal and external wall surfaces.

Thermal insulation and energy conservation in buildings are being actively considered.

Nearly all housing blocks have a painted external finish in different colours. This creates a legacy of costly labour, materials and scaffolding in periodic repainting for the life of the buildings.

E. Centre for Research and Development of
Light Building Materials, Hangzhou

The Centre, the establishment of which is partly funded by UNIDO, is situated in the district of Tianshuiqiao, in the city centre of Hangzhou. The site has been cleared ready for piling. Brickwork to the first storey of the staff housing six storey block has been substantially completed.

Another staff housing block on the opposite side of the main road (Yingbinlu) has been completed and occupied. Pending the completion of construction of the Centre scheduled for the end of 1985, temporary offices in the city have been rented, from which the Centre is fully operational with 305 of its intended 350 full complement in post.

The Centre is organised into four Divisions: research, development, technical information and training, and administration. A number of R & D projects undertaken for the National Committee of Science and the National New Building Materials Corporation on new materials research and design of prototype production lines are either completed or well advanced. Work requiring laboratory facilities are being carried out in collaboration with other research institutes in various parts of China. The first issue of 'Building and Structural Materials', a bi-monthly technical journal, has been published for national circulation by the Centre.

Detailed proposals for equipping the Centre's laboratories are being discussed. The Centre has expressed the hope that UNIDO may be able to assist in funding some of the equipment. Recruitment for the remaining 45 staff, mainly for the Research Division, is now under way. In the meantime, the staff which the expert has met have demonstrated high levels of competence, enthusiasm and vigour in their tasks.

IV. CONCLUSIONS AND RECOMMENDATIONS

The general direction in the development and use of building materials and systems is, with minor exceptions, correctly related to China's conditions. For further improvement it is recommended that:

In the short term:

Bricks should be lightened by introducing 18 to 20% circular perforations by simple modification of the extrusion process;

Brick and concrete should be made and designed to act as external weathering surface without the addition of a painted surface or rendering.

Grooves and vertical stripe patterns should be introduced in rendered or smooth face concrete external surfaces to relieve shrinkage cracking and improve weathering appearance;

Shear wall diagonal reinforcement should be eliminated in large panels, particularly in non-seismic areas;

Hollow cores in precast columns should be eliminated as they serve no useful structural purpose and only add to the complexity in precasting and give an oversize appearance and space obstruction.

In the longer term:

The present flat roofs should be lightened by replacing with low pitch ($17\frac{1}{2}^{\circ}$) concrete interlocking tiles (40 to 50 kg/m^2) on cold rolled steel battens and trusses, particularly in non-seismic areas, or by plastic coated profiled steel sheet (5 kg/m^2) on cold rolled steel lattice beams.

Loadbearing 'no-fines' concrete, which is simple to cast in place and economic in cement consumption should be developed for up to 6 storey buildings. For greater loads a combined reinforced

concrete frame and 'no-fixes concrete infill wall should be used.

Plastic coated profiled steel for external wall cladding should be developed.

Lightweight building systems using cold-formed steel studs as structural frame, lined with gypsum board internally and suitable boards for external exposure, should be developed.

Fire precaution in buildings (fire resistance, spread of flame, means of escape) should be considered. At present little attention is paid to this aspect. Some concrete elements at present produced are so thin that they are unlikely to provide a half-hour fire resistance.

The Centre for Research and Development of Light Building Materials, Hangzhou, should have facilities for the construction and testing of prototype whole buildings.

V. VISITS TO FACTORIES, INSTITUTES AND SITES

A. 20-23 August 1983 Beijing

Jingsun district housing site of large panel concrete, cast in place panel formwork concrete, reinforced concrete frame with brick and block infill walls and gypsum board partition walls with cold rolled steel studs.

Qinghe brick factory producing 52x124x225 mm solid clay bricks, output 150M bricks per year.

Beijing new building materials factory, producing: paper-faced gypsum board 12mm thick (output 20M m² per year); cold rolled pregalvanised steel stud framing, large panel concrete wall panels with mechanised handling of heavy steel moulds and steam curing; rockwool plant producing 16000 tones per year of semi-rigid insulating boards.

Beijing gas concrete factory, producing aerated autoclaved sand-cement blocks and reinforced roof slabs of density 500kg/m³, output 120,000 m³ per year.

B. 24-27 August 1983 Suzhou

Ciixiang village housing, of up to 6 storey precast hollow columns and reinforced concrete ribbed slab with edge beams, non-loadbearing walls of flyash aerated blocks bonded into large panel precast facing concrete panel.

Nanhuan new village housing site, of loadbearing flyash aerated concrete block walls and hollow precast concrete floors, 4 storeys.

Suzhou building elements factory, producing hollow square reinforced concrete columns, ribbed floor slabs with aerated concrete block infill, large panel walls with aerated concrete block infill and aerated autoclaved flyash lime/cement blocks of 500kg/m³ density.

Whole day lecture to about 100 engineers and architects on: System building in the U.K.; Design of lightweight structures; Building failures; Roof and wall cladding materials.

C. 28-31 August 1983 Wuxi

Building structures laboratory.

Cement and concrete building products research institute.

Whole day lecture to about 75 engineers and architects on: System Building in the U.K.; Design of lightweight structures; Building failures; Roof and wall cladding materials.

Wuxi cement products factory, producing hollow prestressed slabs, hollow square reinforced concrete columns and room size roof panels.

A suburban housing site to see a typical 'hard' roof waterproofing construction, consisting of a 20mm cast in place screed over 2 courses of bonded brickwork (120mm thick) over a screed to falls, over hollow prestressed concrete slabs.

Glass fibre production and weaving plant, output 200 tonnes per year mainly for textiles and wallpaper base, but a future possible source of supply of glass fibre mat (when the present factory is moved to a new site with extended capacity) for use as a base material in place of paper base in the production of high performance bitumen roofing felt.

Linung clay brick and tile factory producing solid extruded bricks and single lap interlocking tiles in tunnel kilns as well as research, development and production of brick making machinery for other factories and for export.

D. 1-6 September 1983 Hangzhou

Hangzhou roofing felt factory, output 780,000 rolls per year, of 1m wide by 20m long paper based roofing felt, 28kg per roll, including bitumen processing.

Marble quarry, cutting and polishing factory, producing high quality 'Hangzhou grey' 20mm thick, output 15000m³/year, nearly all for export; adjacent cement works producing white cement using marble waste as raw material.

Xiaohu concrete building products factory, producing large dense concrete hollow blocks up to 1.5mx0.8mx0.2mx2.8cm wall thickness, prestressed hollow slabs, large ribbed prestressed slabs using large steel moulds and mechanised handling and curing chamber.

Site of 8 storey, 740 bedroom Wanghu Hotel, in course of super-structure construction, of precast and cast in place reinforced concrete frame, prestressed hollow slabs, brick infill walls and heat reflecting glazing.

One and a half days lectures to over 100 engineers and architects on: System Building in the U.K.; Building failures; Design of lightweight structures; Condensation control; Energy conservation and thermal insulation in buildings, U.K.; Developments in structural design methods; Roof and wall cladding materials.

Half day technical discussion with about 20 engineers and architects of the Centre for Research and Development of Light Building Materials, on detailed questions concerning the subjects of the lectures.

Half day discussions with senior Ministry, provincial and city staff, engineers and architects on the background, establishment and scope of work of the Centre for Research and Development of Light Building Materials.

Site of Centre for Research and Development of Light Building Materials at Tienshuiqiao in the city centre of Hangzhou. Foundations and part of the ground floor brick walls for the 6 storey housing block had been completed.

E. 7-13 September 1983 Beijing

Three whole-day lectures to over 100 engineers, architects and building materials production technologists on: System Building in the U.K.; Building failures; Design of lightweight structures; Energy conservation and thermal insulation in buildings; Condensation control; Roof and wall cladding materials; Developments in structural design methods and determination of dead, imposed, snow and wind loads; The British Standards Institution and the preparation of British Standards and Codes of Practice for Building and Civil Engineering.

Visit to the Beijing Roofing Felt Factory, capacity 2.5M rolls
1mx20m per year, followed by a lecture to senior managers and engineers
on flat roof waterproofing materials in the U.K..

VI. LECTURES AND TECHNICAL INFORMATION PROVIDED BY EXPERT

A. Lectures

SYSTEM BUILDING IN THE U.K. Development of house-building systems since the 1960s; high rise large panel concrete and cast in place cross-wall concrete systems; low rise no-fines concrete, timber frame and cold-formed steel frame systems; economics and productivity of system building.

BUILDING FAILURES. Progressive collapse of large panel structures; strength reduction of high alumina cement through chemical conversion; steel corrosion in reinforced concrete through use of calcium chloride to accelerate hardening; brickwork wall and reinforced concrete building frame damage due to combined action of irreversible expansion of clay bricks and shortening of concrete frame by shrinkage, elastic shortening and creep.

LIGHTWEIGHT BUILDING DESIGN. Advantages and disadvantages of lightweight buildings; sequence in the development of a lightweight system; choice of structural form; loadbearing cold formed steel stud-frame system which can reduce overall mass of building to 1/5 compared with traditional masonry and concrete construction.

ENERGY CONSERVATION IN BUILDINGS, U.K. Climate; indoor comfort levels; heat loss through various parts of house; U.K. Building Regulations 1982 regarding thermal insulation requirements; methods of reducing heat loss in old and new houses.

CONDENSATION CONTROL IN BUILDINGS. Design assumptions for outdoor and indoor temperatures and humidities in winter and summer; concept of 'warm', 'cold' and 'inverted' roof and wall enclosures for condensation analysis; determination of dew point and calculation of interstitial winter condensation and summer evaporation of condensate; safe levels of winter condensate retention in insulation materials.

ROOF AND WALL CLADDING MATERIALS. External walls; brickwork; the Brepak high pressure hand press for making blocks of clay soil with small amounts of cement or lime added; roof and wall hung concrete

tiles; profiled plastic coated steel sheet cladding; improved bitumen roofing felts of high extensibility and fatigue resistance through use of polyester or glass fibre bases and of polymer and synthetic rubber extended bitumen; asbestos cement sheet and roofing slate; gypsum board for ceiling and wall lining and improvement of fire resistance by addition of glass fibre and perlite in the plaster.

B. Literature

18 sets of selected product data, design manuals, research papers, British Standards 1983 Yearbook, Standards and Codes of Practice, Spon's Architects and Builders Price Book, 1983, which cover the lecture subjects listed above.

C. Slides

About 200 colour slides illustrating use of building materials and systems of building in the U.K..

D. Films

'Redland roofs the world', a 10 minute 16mm colour film provided by courtesy of Redland Roof Tiles Ltd, U.K., showing the worldwide manufacture, research and development and application of concrete roof tiles.

'Bricks and brickwork manufacture', a 15 minute 16mm colour film provided by courtesy of the Brick Development association, U.K., illustrating the manufacture, development and application of clay and calcium silicate bricks.

'Permanite expertise', a 20 minute video tape provided by courtesy of Permanite Ltd, U.K., illustrating the manufacture, development and application of various bitumen roofing felts.

