**Defence Works Functional Standards**

# Guide to World War II Hangars
# 01 - Bellman Hangar

**DEFENCE WORKS SERVICES**
MINISTRY OF DEFENCE

**DEFENCE WORKS SERVICES**
MINISTRY OF DEFENCE

**Defence Works Functional Standards**

# Guide to World War II Hangars
# 01 - Bellman Hangar

**MARCH 1995**
COMPILED BY AIRFIELDS & BULK FUELS GROUP (ABFG)
DEFENCE WORKS SERVICES

# Acknowledgement

Defence Works Services would like to express their thanks to The British Constructional Steelwork Association Limited (BCSA) for their permission to reproduce tables from the Historical Structural Steelwork Handbook. DWS would also like to extend their gratitude to the British Standards Institution for permission to reproduce the UK map of wind speeds.

# Foreword

This Standard was prepared under the patronage of HQ STC.

This document is intended for use by Project Sponsors, Property Managers (PROMs), Establishment Works Consultants (EWCs), Works Services Managers (WSMs), Project Managers (PMs) and any other MOD staff using the Bellman hangar or engaged in duties connected with the hangar.

MOD addressees should ensure that designers and contractors employed for works connected with the Bellman hangar are advised of the Functional Standard.

Amendments to this Functional Standard will be advised by DWS Technical Bulletin and it is the responsibility of the reader to check with the PM or Project Sponsor if amendments have been issued. A sheet is provided to record amendments.

A Change Suggestion Form is included at Annex A for feedback on suggested changes and development of the Functional Standard. All readers of the document are requested to send the form to the DWS Technical Authority giving details of any suggestions they may have.

In making reference to any publication mentioned in this Functional Standard, readers should check the latest edition from its publisher.

Any reference to works or project in this Functional Standard should be interpreted to mean either "works services" with estimated cost currently below £300k overall or "project" with estimated cost above £300k overall (NB inclusive of professional fees and VAT).

The DWS Technical Authority on hangar buildings is:

Structures Section<br>
Airfields and Bulk Fuels Group<br>
P O Box 1734<br>
Sutton Coldfield<br>
West Midlands B75 7QB

All enquiries in connection with drawings and requests for copies of drawings should be addressed to:

The Library<br>
HQ DWS<br>
P O Box 1734<br>
Rectory Road<br>
Sutton Coldfield<br>
West Midlands B75 7QB

Every care has been taken in the preparation and presentation of this document, but the information provided is for guidance only and it must be verified and checked for each individual project.

# Amendments

| Amendments | Page No | Date | Inserted By |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# Abbreviations

| | |
|---|---|
| BS | British Standard |
| DCI | Defence Council Instruction |
| DWS | Defence Works Services |
| EWC | Establishment Works Consultant |
| HQ STC | Headquarters Strike Command |
| JSP | Joint Services Publication |
| MHE | Mechanical Handling Equipment |
| MOD | Ministry of Defence |
| PM | Project Manager |
| PROM | Property Manager |
| TB | DWS Technical Bulletin |
| WSM | Works Services Manager |
| pc | permissible axial stress in compression |
| pt | permissible axial stress in tension |
| pbc | permissible bending stress in compression |
| pbt | permissible bending stress in tension |

CONTENTS

PAGE LEFT INTENTIONALLY BLANK

# 1.0 INTRODUCTION

This Functional Standard is a guide to the Bellman hangar, for use by all those from within MOD or from external organisations, engaged in works or duties connected with the hangar.

The Bellman hangars are in active use on the MOD estate. Many of these hangars are subject to maintenance, repair and refurbishment works depending upon the condition of a particular hangar, its current and future use and predicted life span.

The Functional Standard describes the typical Bellman hangar, how it can be identified, its typical structural form and features. It records the Archive Drawings available on microfilm and the new Typical Drawings that were prepared, illustrating a typical Bellman hangar.

The long held view within MOD is that wartime hangars have inherent weaknesses in their structural strength, particularly the lightweight hangars such as the Bellman. Three Bellman hangars are reported to have collapsed in Scotland during extreme weather conditions although further details as to the exact nature of the collapses are not available.

In view of the above, an in-depth analysis of the Bellman structure was carried out to determine its strength. The results of the structural appraisal confirmed that there existed serious deficiencies in the strength of the Bellman hangar, in that it fell significantly below current standards for design and loadings. The degree of shortcomings in the hangar's strength depended on its location within UK as this determined the wind and snow loadings applied to it.

This Functional Standard explains how the Bellman structure was appraised, the design philosophy adopted and findings of the analysis. The historical design codes and steelwork stresses and the current loading criteria are covered. The significance of dominant openings in a hangar building due to door and window openings and the building's permeability is also explained.

Due to concerns about weaknesses in the structural strength of wartime hangars, operational constraints had to be put in force. These constraints, in the main, required hangar doors to be kept shut and the structure put under observation during adverse weather conditions of snowfall and high winds.

Subsequent to imposition of the above constraints, the in-depth structural analysis of the Bellman hangar gave rise to fears of the potential for collapse of some of these hangars under certain adverse weather conditions. This led to specific instructions being given by DWS for additional precautionary actions to be taken in connection with the Bellman hangars, involving evacuation of personnel during snowfall and high winds.

The Functional Standard covers general hangar refurbishment and the common work items which a PROM or Project Sponsor will be involved with, e.g. roof and wall re-cladding, doors, floors, etc. Guidance is given in respect of MOD policy, working practices and any other standards or codes that are applicable, depending upon the particular work item under consideration. Typical solutions are given with illustrations for strengthening the Bellman structure and its foundations.

MOD Fire Standards directly applicable to hangars are explained, including MOD policy on their application during refurbishment works. The application or otherwise of Building Regulations can in certain circumstances be difficult to interpret, and suitable guidance is given to overcome ambiguity. During major refurbishment works on a hangar, Project Sponsors may be compelled to upgrade the hangar in order to comply with statutory requirements, i.e. structural safety, fire regulations, etc.

Any planned hangar works cannot be analysed without an estimate of costs. Limited information is available on cost estimates during refurbishment works, including costs for strengthening of structure, re-cladding, etc. In selecting the most economical option during hangar works, the option of a new build alternative should not be ignored. Cost estimates of a new build hangar are also given, enabling comparisons to be made.

In selecting the option of whether an existing Bellman hangar is refurbished and upgraded to comply with statutory requirements and MOD standards or to demolish and build a new hangar, it is realised that capital costs are generally similar for the two options. A site specific structural appraisal is therefore recommended with all the options for a project being considered according to their particular circumstances. An investment appraisal should be carried out based on cost estimation using risk analysis. The professional judgement for the safety of structure and its economic viability, taking into account factors such as predicted future uses, projected life span requirement and the operational consequences of a hangar being out of use during construction works, should be given due consideration. A well balanced and measured approach can then be taken for a project's viability.

Where a hangar is in its original state i.e. without having been strengthened, re-clad or refurbished, the choice between upgrading the existing hangar and a new build hangar is a simple one, largely dependent upon a site specific investment appraisal. Given equal considerations, this will often lead to the fact that a new build hangar is a better and more economical option. It will also have the advantage of incorporating current user requirements as against making impromptu arrangements. The maintenance, repair and running costs will also prove to be lower.

When a hangar has already been refurbished and its cladding renewed, the choice between upgrading the hangar in view of any structural weakness and new build can be difficult, in that despite major expenditure the operating restrictions on the use of the hangar during adverse weather conditions will continue to remain in force unless the structure is strengthened and this is not easy particularly when new cladding is in place. The investment appraisal using risk analysis then becomes a much more demanding and sensitive exercise.

# 2.0 BACKGROUND

It is estimated that approximately 100 Bellman hangars exist throughout UK. The hangars were built around World War II, during late 1930s to early 1940s, and are still in use on the MOD estate. The Bellman hangars were often referred to as "transportable sheds" due to the fact that their modular design meant that they could be dismantled and transported to a new location for reuse.

Many of the wartime hangars were erected as temporary structures in anticipation of a short design life. They were produced in order to provide a fast, economical solution to a need for hangars before and during World War II. They were built hastily and over a short period of time, with many `enjoying' emergency relaxation of design standards. The envisaged short term exposure to wind and snow loading would have allowed smaller loadings to be considered than is the case for long term exposure as the magnitude of the design load is dependent upon the life of the structure.

It is believed that Bellman hangars were built at locations as listed below. The list is not authentic and it is given for information only, subject to confirmation. It is noted that a number of the stations listed below may have closed. Also some Bellman hangars at the respective locations may be permanently out of use or they may have been demolished.

DRA Aberporth
RAF Aldmondbank
RAF Aston Down
RAF Brize Norton
RAF Church Fenton
RAF Cosford
RAF Dallcross
RAF Exeter
RAF Fleetlands
RAF Henlow
RAF Kemble
RAF Leuchars
RAF Locking
RAF Lossiemouth
RAF Mildenhall
RAF Montrose
RAF North Coates
RAF Quedgeley
RAF Shawbury
HMS Sultan
RAF Sydenham
RAF Valley
RAF Woodvale
RNAS Yeovilton
RAF Aldergrove
RAF Arbroath
Britannia Royal Naval College
RAF Chivenor
RM Condor
HMS Daedelus
RAF Dyce
RAF Fauld
RAF Halton
RAF Inverness
RAF Kirknewton
DRA Llanbedr
Army Long Kesh
RAF Lyneham
RAF Mona
RAF Netheravon
RNAS Portland
Army Shackleton Barracks
RAF St Athan
RAF Sumburgh
RAF Tern Hill
DRA West Freugh
RAF Wroughton

**PAGE LEFT INTENTIONALLY BLANK**

# 3.0 GENERAL ARRANGEMENT

## 3.1 IDENTIFICATION AND DESCRIPTION

In dealing with any hangar works, it is vital that the hangar type is correctly identified. Some hangars have only minor differences between them and any doubts about identification of the Bellman hangar can be clarified with the DWS Technical Authority.

At first glance the Bellman and Type T2 hangars appear very similar, but the doors of the Bellman run level with the top of the side panelling, whereas T2 hangars have panelling above the doors before the roofing commences. See photos 3.1 and 3.2.

Another distinction between the Bellman and Type T2 is the lattice portal frame units. The lattice arrangement for the Type T2 is a Warren type i.e. with all internal web bracing members as diagonals whereas for the Bellman the internal web bracing members are similar to the Type T2 but with additional vertical members (NB horizontal in columns) at each node. See photos 3.3 and 3.4.

Each gable end has six sliding doors allowing an opening the full width of the hangar to be formed. Some hangars may now have operational doors on one end only, the other end with doors permanently locked. There is a top roller guide and the doors slide on a roller track bottom.

DWS Drawing Nos D/DWS/H1/003/001 & 2 show basic details and dimensions and reduced size copies are included in this chapter. The drawings should be referred to for identifying and understanding the form of the Bellman hangar.

The Bellman hangar is a lightweight structure made from steel lattice portal frames. The portal frames form 14 bays to give an overall length and width of 53.340m and 28.956m respectively. There are two heights of the hangars, those with 3 standard unit columns (8.35m to eaves) and those with 2 standard unit columns (5.91m to eaves).

Two basic units were used to form the Bellman hangar, these being the column and rafter standard units approx 2.44m long and 0.71m wide comprising back to back angles as boom members and single channels as ties/diagonals, and the eaves units which are of slightly heavier construction than the standard units and form a corner unit at the head of the columns. The eaves units join the columns to the rafters, the latter consisting of 10 standard units, 5 in each half of the portal frame. The bottom column standard unit sits on a base plate arrangement at the foundations. The connections of the diagonals to the booms within the standard and eaves units are either welded or, as is implied by some of the Archive Drawings, riveted. Whilst the welded connections do form rigid joints, the narrowing of the section at these joints and the weld detail mean that full fixity will not be achieved. However, the benefit of assuming such joints to be fixed is marginal and, when it is considered that some Bellmans may be riveted, the assumption of pinned joints is not onerous.

PAGE LEFT INTENTIONALLY BLANK

Photo 3.1 External View of Bellman Hangar

Photo 3.2 External View of Type T2 Hangar


Photo 3.3 Lattice Portal Frame of Bellman Hangar

Photo 3.4 Lattice Portal Frame of Type T2 Hangar

Connections between units comprise spliced joints consisting of eight bolts in shear via a fishplate, four in each half. In addition, there are two bolts in line taking direct tension. This is a poor detail as the in-line bolts will tend to take the load immediately, but those in shear can only resist the load after some movement has occurred. Considering the longevity of the hangars, the full capacity of all the bolts can be assumed.

The secondary members consist mostly of pressed metal 'U' shaped sections for the purlins, sheeting rails, rafter stays and wind bracing. All connections are bolted together to form the structure.

The original roof covering was corrugated galvanised iron sheeting or canvas sheeting but some hangars are known to have been re-clad using pressed and profiled metal sheeting possibly using insulation.

The foundation units comprise two 102 x 51mm (4" by 2") rolled steel channels back to back, approx 2.1m long. The bottom column unit sits centrally on the foundation unit and is bolted to it. The foundation units have a corrugated metal base at each end of the rolled steel channels which can be spiked to the ground. The corrugated metal bases sit on either compacted hardcore, timber sleepers or individual concrete pads. In some special instances the bases are founded on one large concrete pad, the full plan size of the foundation unit.

## 3.2 DRAWINGS

Archive Drawings of the Bellman hangar are available on microfilm. There are no records of site specific as-built drawings, unless these are available from a PROM or Project Sponsor at the particular site. The Archive Drawings appear to be authoritative records of the Bellman hangar, as seen during site inspections.

The microfilms appertaining to the Bellman hangar are listed in Table 3.1. It cannot be confirmed whether the drawings list is 100% complete i.e. representing all the drawings as originally produced. The drawings give an outline of the structure and its component parts. The quality of the microfilming is poor in some cases and the extent of the drawings is not comprehensive enough to fully define the structure, especially when considering the foundations. The drawings on microfilm can be viewed on a projector, subject to prior arrangements with the Library at HQ DWS, at the address given in the Foreword to the Functional Standard.

The examination of microfilmed drawings and collation of information obtained from site inspection has enabled two Typical Drawings to be produced, showing the structural form of the Bellman hangar. The general arrangement of steelwork and foundations are detailed in Drawing Nos D/DWS/H1/003/001 and 002. The Typical Drawings were produced in AutoCAD form at A1 size. A reduced size copy of each of the Typical Drawings is included at the end of this chapter. These drawings form the basis of the assumptions made in the structural appraisal of the Bellman hangar, assisted by Archive Drawings where appropriate.

The Typical Drawings convey DWS' understanding of the Bellman hangar. If an on-site inspection reveals any deviations from the Typical Drawings, then suitable allowances should be made to the guidance and recommendations in the Functional Standard in line with the nature and scale of deviations.

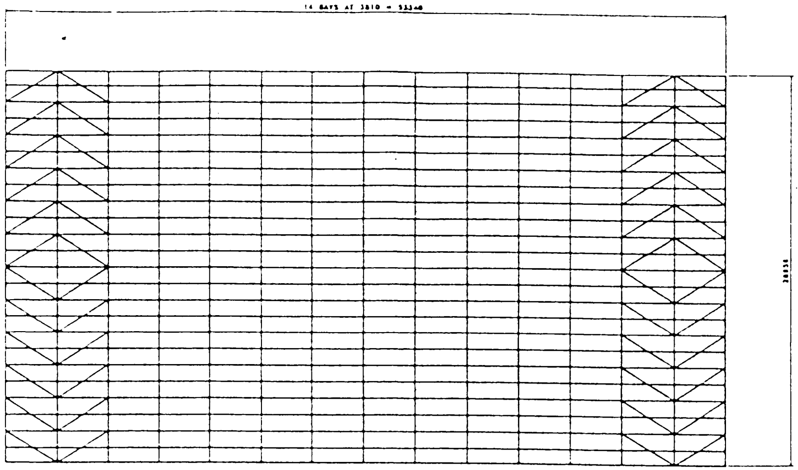
It is noted that some standard units on a few Bellman hangars that were inspected were inserted upside down. A trial analysis of this situation revealed minor rearrangement of loading in members within and adjacent to the inverted unit, but the loadings were not generally more onerous than when the units were inserted correctly. Whilst inverted units are a structural deficiency it is not thought that urgent remedial action is warranted, however during refurbishment consideration should be given to retrofitting angle bracing into the units to mimic the original designer's intentions.

The bracings should be given particular attention to ensure that all members are correctly in place. The on-site inspection must also ensure that the maintenance condition of the hangar is satisfactory and will not adversely affect its structural strength.

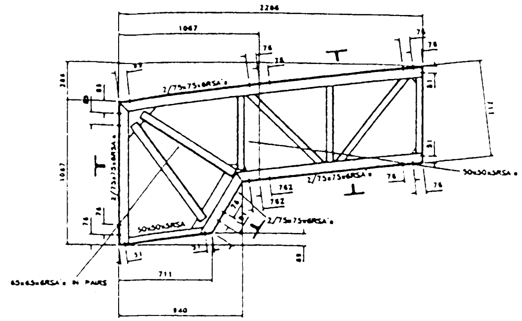
| Drawing Title | Subject | Original Drg No | New DWS Drg No | Microfilm No (Cat No) |
|---|---|---|---|---|
| Transportable Hangars, Bellman Type | Quantity Lists for Bellman Hangars Showing Bolts etc | 13929/40 | DWS/H4/003/001 | 0353721 (21) |
| Transportable Shed, 175' long by 95' wide by 25' clear height | Erection Drawing and General Arrangement Showing Canvas Doors | 8349/37 | DWS/H4/003/002 | 0353758 (2) |
| Transportable Aeroplane Shed | Details of Units for One Shed | 8350/37 | DWS/H4/003/003 | 0353757 (4) |
| Transportable Aeroplane Shed (Canvas Doors) | Details of Units for Ends Over Doors, Door Tubes, Top and Bottom Tracks and Hood etc | 8351/37 | DWS/H4/003/004 | 0353762 (6) |
| Transportable Aeroplane Shed | Details of Oiled Fabric and Canvas | 8352/37 | DWS/H4/003/005 | 0353763 (7) |
| Transportable Aeroplane Shed | Details of Sheeting etc For One Shed | 8353/37 | DWS/H4/003/006 | 0353764 (8) |
| Transportable Aeroplane Shed | Excavation Plan For Sheds with Canvas Doors | 8354/37 | DWS/H4/003/007 | 0353765 (9) |
| Transportable Aeroplane Shed (Steel Doors) | Details of Door Frame Units Top Roller, Bottom Wheels, etc Welded Construction | 8355/37 | DWS/H4/003/008 | 0353766 (10) |
| Transportable Aeroplane Shed (Steel Doors) | Details of Units For Top and Bottom Tracks, Sleepers, Hood Flashing and Corner Guide Rail Brackets | 8356/37 | DWS/H4/003/009 | 0353760 (11) |
| Transportable Hangar Steel Doors | Modification to AM Drg Nos 8355/37 and 8356/37 for Rivetted Construction Instead of Welding | 8357/37 | DWS/H4/003/010 | 0353767 (13) |
| Transportable Hangar Steel Doors | Modifications to AM Drg Nos 8355/37 and 8356/37 for Rivetted Construction Instead of Welding | 8358/37 | DWS/H4/003/011 | 0353769 (14) |
| Transportable Aeroplane Sheds | Details of Door Stops, Locking Cleats. Detail of Welding to Units. Galvd. Wire Rope for Doors. | 8359/37 | DWS/H4/003/012 | 0353770 (15) |
| Transportable Aeroplane Hangar | Details of Corner Units Mark 2 | 8360/37 | DWS/H4/003/013 | 0353771 (16) |
| Transportable Aeroplane Shed (Bellman Type) | Foundations. Special Design To Be Used Only When Directed. | 6411/39 | DWS/H4/003/014 | 0353724 (20) |

Table 3.1 List of Archive Drawings on Microfilm

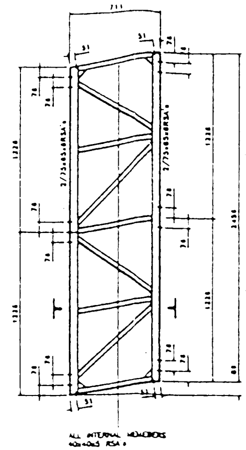
**PAGE LEFT INTENTIONALLY BLANK**



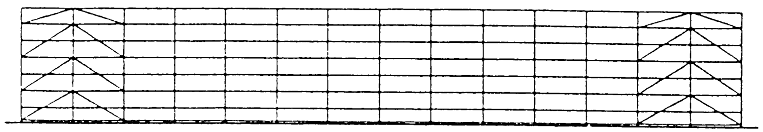

PLAN ON ROOF



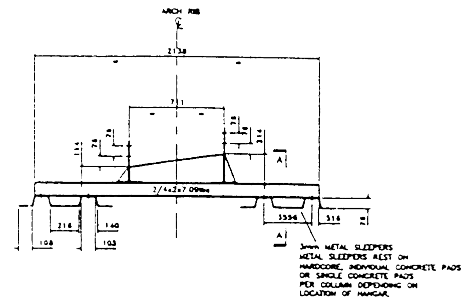

STANDARD EAVES UNIT



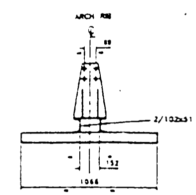

STANDARD UNIT



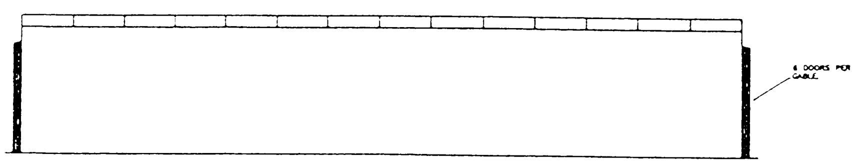
SIDE ELEVATION SHOWING PURLINS AND BRACING



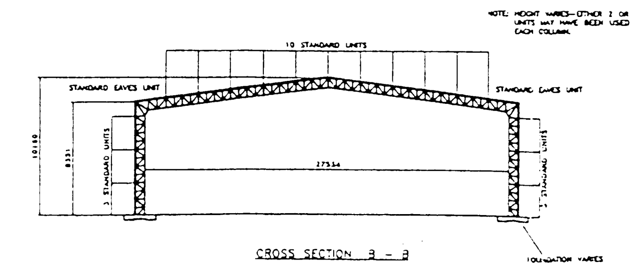

STANDARD BASE UNIT



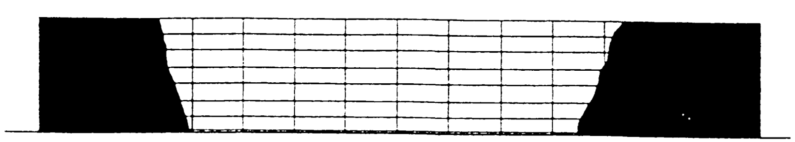

SECTION A - A



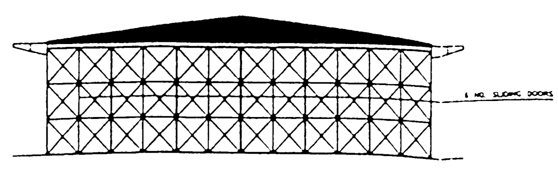

LONGITUDINAL CROSS SECTION A - A




CROSS SECTION B - B




SIDE ELEVATION




GABLE ELEVATION

Do not scale

NOTES

1. THE INFORMATION SHOWN ON THIS DRAWING HAS BEEN PREPARED FROM ORIGINAL AIR MINISTRY 'TYPE DRAWINGS' OF VARIOUS SOURCES AND THEREFORE ITS RELEVANCE TO ANY SPECIFIC HANGAR MUST BE CONFIRMED BY A SITE SURVEY. THE ORIGINAL DRAWINGS WERE PREPARED IN IMPERIAL UNITS AND DURING THE PROCESS OF METRICATION SOME ROUNDING OFF ERRORS MAY HAVE OCCURED.

| Issue | Date | Change No. | Issue | Date | Change No. |
|---|---|---|---|---|---|

Revisions

DWS
Defence Works Services

PO Box 1734
Rectory Road
Sutton Coldfield
West Midlands B75 7QB

Technical Authority: STRUCTURES SECTION/ABFG

| | Company | Contract No. | Signature | Date |
|---|---|---|---|---|
| Drawn | WHITE YOUNG | WS 13/1944 | [signature] | 12 10 94 |
| Design | — | — | | |
| Checked | WHITE YOUNG | WS 13/1944 | [signature] | 12 10 94 |
| Approved | | | | |
| Date | | | | |

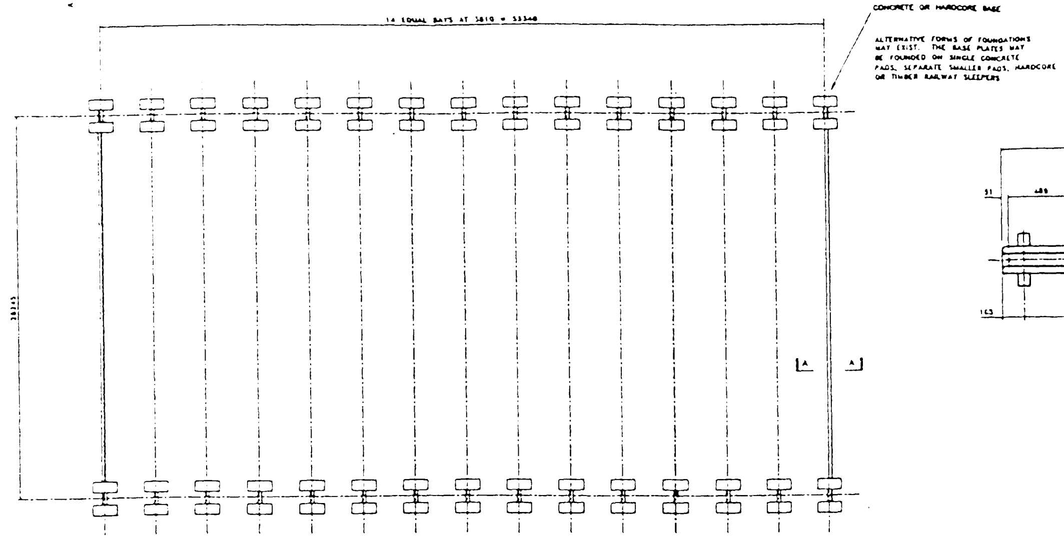
Security Classification: UNCLASSIFIED

DWS File Ref: D/DWS/C1/04363

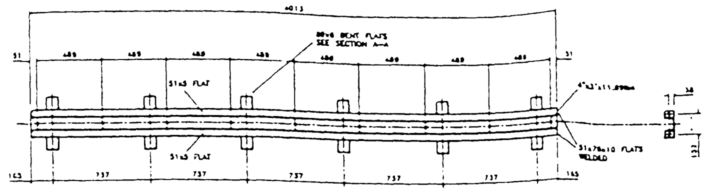
Facility / Location Name: BELLMAN HANGARS

Drawing Title: G.A. OF STEELWORK AND STANDARD UNITS

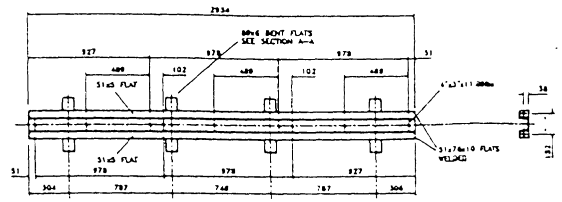
DWS Drawing No. | Rev



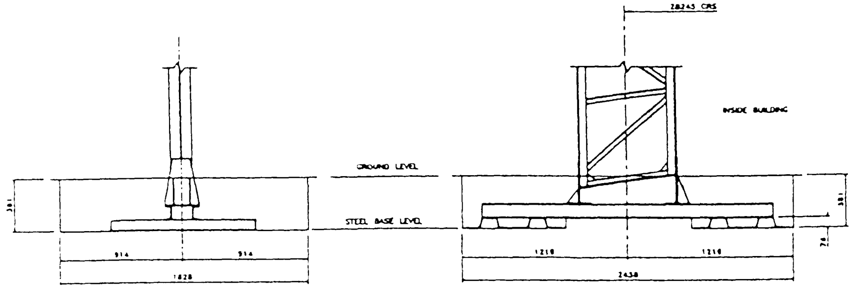

PLAN ON FOUNDATIONS

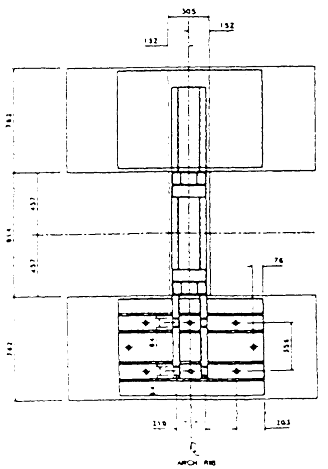



DOOR GUIDE 4 NO REQD. PER HANGAR

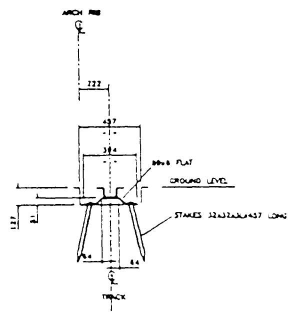



DOOR GUIDE 16 NO REQD. PER HANGAR

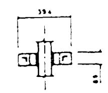



DETAILS OF FOUNDATION TO MAIN FRAMES




SECTION A – A
DOOR TRACK FOUNDATION




PLAN ON GUIDE
RAIL SUPPORT

Do not scale

NOTES.

1. THE INFORMATION SHOWN ON THIS DRAWING HAS BEEN PREPARED FROM ORIGINAL AIR MINISTRY "TYPE DRAWINGS" OF VARIOUS SOURCES AND THEREFORE ITS RELEVANCE TO ANY SPECIFIC HANGAR MUST BE CONFIRMED BY A SITE SURVEY. THE ORIGINAL DRAWINGS WERE PREPARED IN IMPERIAL UNITS AND DURING THE PROCESS OF METRICATION SOME ROUNDING OFF ERRORS MAY HAVE OCCURED.

| Issue | Date | Change No. | Issue | Date | Change No. |
|---|---|---|---|---|---|
| | | | | | |

Revisions

DWS
Defence Works Services

PO Box 1734
Rectory Road
Sutton Coldfield
West Midlands B75 7QB

Technical Authority: STRUCTURES SECTION/ABFG

| | Company | Contract No. | Signature | Date |
|---|---|---|---|---|
| Drawn | WHITE YOUNG | WS 13/1944 | [signature] | 10.9_ |
| Design | — | — | | |
| Checked | WHITE YOUNG | WS 13/1944 | [signature] | 12 10 9_ |
| Approved | | | | |
| Date | | | | |

Security Classification: UNCLASSIFIED

DWS File Ref: D/DWS/C1/04363

Facility / Location Name: BELLMAN HANGARS

Associated Drg. Nos.

Drawing Title: DETAILED G.A. OF FOUNDATIONS.

DWS Drawing No.

Rev.

# 4.0 STRUCTURAL APPRAISAL

The Structures Section, ABFG undertook a structural appraisal of the Bellman hangar in order to determine its capacity. The design philosophy adopted, the design and loading codes used and the results of the structural analysis are discussed in this Chapter. The assumptions made for the appraisal may vary from site specific conditions of a particular hangar, including the environmental conditions, predicated future uses, projected life span, etc. Hence it is recommended that suitable allowances are made for deviations from assumptions made in this Functional Standard and that a site specific analysis is always considered before drawing any firm conclusions.

## 4.1 DESIGN PHILOSOPHY

There is no absolute measure of adequate safety and even less of serviceability. There does however exist a generally accepted level of safety provided by design and construction practice in accordance with current regulations and codes of practice. It is recommended that these levels of safety should be taken as datum. Whilst assessing an existing structure, sound engineering judgement is to be exercised in the degree of application of these standards and this should take precedence over compliance with detailed clauses of codes.

There are two extant British Standards which can be used in the design of steel frame buildings; namely BS 5950 and BS 449. Great debate exists as to which of these two codes is more appropriate for the analysis of historical structures and the final selection should be based upon professional judgement dependent upon the particular circumstances of the structure in question. After discussions with British Steel and others, the design work undertaken for this Functional Standard has been in accordance with the current edition of BS 449 incorporating Amendment No 8, December 1989 (AMD 6255). It is recommended that future design work should adopt this approach. However, if it is thought more appropriate to use BS 5950, then great care must be taken in the selection of appropriate yield strengths.

## 4.2 DESIGN AND LOADING CODES

### 4.2.1 Wind Loading - Dominant Openings

Wind loading on a large lightweight structure such as the Bellman hangar is of great significance and care should be taken to ensure that all of its effects are appreciated. Wind loads should be assessed by using BSI CP3: Chapter V: Part 2: 1972 as revised up to Amendment No 5 dated 15 September 1993. In addition the effects of dominant openings allowing increased internal pressures to occur should be taken into account, affecting loading on external walls and roof. The internal pressure is primarily controlled by the size of all openings which connect the inside to the outside of the building and the permeability of the building.

In determining the minimum size of a dominant opening, i.e. an opening large enough to allow internal pressures to be affected by the external pressure on a face of the building, Building Research Establishment (BRE) Digest No 346 should be followed. The empirically based definition for "dominant" openings is taken as "when the opening is twice as large as the sum of the permeability of the rest of the building". Openings of this size or larger should be taken as "dominant". For the three unit high Bellman hangar, the dominant opening limit based on permeability of 0.1% of the total wall and roof area is 5.2m$^2$, which equates to a main gable door to be open only 0.7 metre wide. This is too small to classify all but personnel doors as non-dominant openings hence it can be assumed that the structure is subject to internal wind pressures due to a dominant opening in one of the gable ends.

Internal pressures in a hangar can result in reversal of stresses induced in the portal frame and also cause "uplift" of the whole structure including foundations.

### 4.2.2 Wind Loading - Geographical Distribution

An important factor to be considered when assessing the wind load on a structure is that of location. The basic wind speed, and hence wind load, varies with site location. Three different basic wind speeds were considered as follows:

a. Wind Speed less than 45 m/s.

b. Wind Speed greater than 45 m/s but less than 48 m/s.

c. Wind Speed greater than 48 m/s but less than 52 m/s.

The above groupings were chosen after consideration of the distribution of known Bellman hangars in relation to "Map of United Kingdom Showing Basic Wind Speed" from CP3: Chapter V: Pt 2: 1972 which is reproduced at Figure 4.1 overleaf. If a hangar lies outside the limits of group c above, then the effect of wind must be considered accordingly.

The basic wind speed is the 3-second gust speed, at 10 metres above ground in an open situation, estimated to be exceeded on the average once in 50 years.

For the structural analysis of the typical Bellman hangar, the factors applied to the basic wind speed for determining the design wind speed were as follows:

Topography factor S1 = 1.0.

Ground roughness, building size and height above ground factor S2 as applicable, corresponding to ground roughness category (1).

Statistical factor S3 = 1.0.

Directional factor S4 = 1.0.

For map of the United Kingdom showing the Basic Wind Speed.
See the British Standard CP3: Chap V: Part 2: 1972. Fig 1.

Figure 4.1 Basic Wind speed in United Kingdom

It is important to note that the above factors will require to be verified or adjusted for each specific site appraised. The S3 factor of 1.0 is for a 50 year period of exposure to the wind. Where it can be confirmed that a hangar will be required for a shorter period, then an S3 factor of less than 1.0 may be used. However, experience has shown that MOD buildings are often retained long after their intended life span and therefore an S3 factor of less than 1.0 should only be adopted in exceptional circumstances and following careful consideration of the project.

### 4.2.3 Dead Loads

The dead load imposed on the structure should be assessed from the actual form of construction noted for a particular hangar. The dead load assumed in the appraisal is 0.27 kN/m$^2$. This figure includes 0.10 kN/m$^2$ for the use of modern lightweight cladding systems with integral insulation to give a 'U' value of 0.45 W/m$^2$K. Depending on the type of cladding system used, the dead load assumed should be adjusted accordingly.

### 4.2.4 Service Loads

Adequate allowances should be made for the provision of services fixed to the roof of a hangar, such as lighting, heating and ventilation units. The requirements of each hangar should be assessed on a case by case basis, but unless advised otherwise by the Property Manager, a minimum loading of 0.15kN/m$^2$ should be allowed.

### 4.2.5 Imposed Loads

The imposed load upon the structure will be that due to snow loading. Snow loads should be calculated in accordance with BS 6399: Pt 3: 1988 "Code of Practice for Imposed Roof Loads". The code gives the map of UK showing the variation in basic snow load with location and this is reproduced as Figure 4.2. The snow load on the roof ($s_d$ kN/m$^2$) is determined by multiplying the estimated snow load on the ground at the site location and altitude (the site snow load $s_o$ kN/m$^2$) by a factor known as the snow load shape coefficient ($u_i$), i.e. $s_d = u_i s_o$. The site snow load $s_o$ equates to the basic snow load $s_b$ as per Figure 4.2 for sites whose altitudes are not greater than 100m.

After considering this distribution and the requirements of Clause 4.3.1 of the code, which states that a minimum imposed roof load of 0.6kN/m$^2$ must be allowed for access and maintenance, it is recommended that this value is used for the Bellman hangar. In the majority of England and Wales, and the southern regions of Scotland, this minimum imposed maintenance load will produce the worst design case. However, in certain locations in the north of Scotland, higher snow loads may determine the minimum imposed load.

For map of the United Kingdom showing the Basic Snow Load on the Ground.
See the British Standard 6399: Part 3: 1988. Fig 1.

Figure 4.2 Basic Snow Load on the Ground

For the analysis of existing buildings the use of a minimum loading of 0.6 $kN/m^2$ is sometimes considered as excessive, and it has often been postulated that the basic snow load on the ground, modified by the appropriate factors in BS 6399 could be used. However, it should be remembered that where major refurbishment is being considered, and the Building Regulations invoked, the 0.6 $kN/m^2$ is a Building Regulations requirement. If a lesser figure is used, dispensation from a Building Control Officer will be required. It is therefore considered prudent and good engineering practice to use the value of 0.6 $kN/m^2$ as the starting point for all analyses, whether it is for routine appraisals or to support major refurbishment.

### 4.2.6 Steelwork Design Stresses

In the absence of original steel certificates or design calculations, the interpretation of permissible design stresses applied at the time requires sound engineering judgement coupled with knowledge of developments in iron and steel construction in UK and Europe from the turn of the century.

Invaluable data on steelwork properties is contained in "Historical Structural Steelwork Handbook - Properties of UK and European Cast Iron, Wrought Iron and Steel Sections including Design, Load and Stress Data since the Mid 19th Century", Publication No 11/84, published by The British Constructional Steelwork Association Limited, ISBN 0 85073 015 5.

The permissible axial stresses in tension (pt) and in compression (pc) for mild steel beams pre-1938 as quoted in Section 6 of the above handbook are as follows:

pt = 8.0 tons/sq inch (123.6 $N/mm^2$)

pc = 8.0 tons/sq inch (123.6 $N/mm^2$, pc is based on a theoretical maximum for a slenderness ration of 0).

Table 6.4 in the Historical Structural Steelwork Handbook giving values of permissible stresses to BS 449 has been reproduced as Table 4.3 for reference.

During the period 1940-1945 revisions were issued to BS 449 for war time emergency relaxation of standards. These relaxations permitted axial compression (pc) with lateral restraint and bending stresses (pbt or pbc) to be increased to 10 tons/sq inch (154.4 $N/mm^2$). This value was partly rescinded to 9 tons/sq inch after the war.

Where a BS 449 type approach is being adopted it is recommended that permissible stress values of 8 tons/sq inch are most appropriate to the Bellman hangar unless other evidence is available to suggest that steel quality is higher for the particular structure being considered. As an example, such evidence may be from sufficient samples taken from the structure for testing, bearing in mind the inconsistency of steel quality achieved during the war.

| WORKING STRESSES in tons/sq in to BS 449 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Steel Grade** | **Tension** Thickness (ins) | Stress | **Compression (Maximum)** | **Bending** Thickness (ins) | Stress (Maximum) | **Shear** Max Stress | Thickness (ins) | Average Stress | **Bearing** |
| 1932 | MS | | 8 | 8 | | 8 | 5 | | | |
| 1935&37 | MS | | 8 | 8 | | 8 | 5 | | | |
| | HY | | 12 | 12 | | 12 | 7.5 | | | |
| 1939&40 (Amdts) | MS | | 8 | 10 | | 10 | 5 | | | |
| | HY | | 12 | 12 | | 12 | 7.5 | | | |
| 1948 | MS | | 9 | 9* | | 10 ( 9.5) | 6.5 | | | 12 |
| | HY | ≤1.75 | 13.5 | 13.5 | ≤1.75 | 15 (14.5) | 9 | | | 18 |
| | | >1.75 | 11.5 | 13.5 | >1.75 | 13 (12.25) | 8 | | | 18 |
| 1959 | MS | ≤1.50 | 9.5 | 9.5 | ≤1.50 | 10.5 (10.0) | 7.0 | ≤0.75 | 6.0 (6.0) | 12.0 |
| | | >1.50 | 9.0 | 9.5 | >1.50 | 10.0 ( 9.5) | 7.0 | >0.75 | 6.0 (5.5) | 12.0 |
| | HY | ≤2 | 13.5 | 13.5 | ≤2 | 14.5 (13.5) | 10.0 | ≤2 | 8.5 (8.0) | 17.0 |
| | | >2 | Ys / 1.63 | 13.5 | >2 | Ys (Ys) / 1.52 ( 1.63) | Ys / 2.2 | >2 | - (7.0) | 17.0 |

* for discontinuous angle struts; MS-6. HY-9      ( ) values refer to plated members

Note: This table cannot cover all the nuances of the standard, thus for detailed requirements reference must be made to the original text of BS 449.

MS refers to mild steel to BS 15      HY refers to high yield steel to BS 548 before 1959 and to BS 968 after 1959

TABLE 4.3 Extract from Historical Structural Steelwork Handbook

| Column stress to BS 449 1937 | | |
|---|---|---|
| Slenderness ratio c = effective L / min.r | Axial stress pc in tons/sq inch | Axial stress pc in N/mm² |
| 20 | 7.17 | 110.7 |
| 30 | 6.92 | 106.9 |
| 40 | 6.64 | 102.6 |
| 50 | 6.30 | 97.3 |
| 60 | 5.89 | 91.0 |
| 70 | 5.41 | 83.6 |
| 80 | 4.88 | 75.7 |
| 90 | 4.33 | 66.9 |
| 100 | 3.81 | 58.8 |
| 110 | 3.34 | 51.6 |
| 120 | 2.93 | 45.3 |
| 130 | 2.58 | 39.8 |
| 140 | 2.28 | 35.2 |
| 150 | 2.02 | 31.2 |
| 160 | 1.81 | 28.0 |
| 170 | 1.62 | 25.0 |
| 180 | 1.46 | 22.5 |
| 190 | 1.33 | 20.5 |
| 200 | 1.21 | 18.7 |
| 210 | 1.10 | 17.0 |
| 220 | 1.01 | 15.6 |
| 230 | 0.93 | 14.4 |
| 240 | 0.86 | 13.3 |

Table 4.4 Extract from Historical Structural Steelwork Handbook

| ALLOWABLE STRESSES IN RIVETS AND BOLTS in tons/sq inch | | | | | | |
|---|---|---|---|---|---|---|
| Stress | Rivets | | | Bolts | | |
| | Type | MS | HT | Type | MS | HT |
| 1932 | | | | | | |
| Tension | Shop | 5 | | ≥0.75"Ø | 5 | |
| | Site | 4 | | <0.75"Ø | 0 | |
| Shear | Shop | 6 | | Turned | 6 | |
| | Site | 5 | | Black | 4 | |
| Bearing | Shop | 12 | | Turned | 12 | |
| | Site | 10 | | Black | 8 | |
| 1935 & 1937 | | | | | | |
| Tension | Shop | 5 | 7.5 | ≥0.62"Ø | 5 | 7.5 |
| | Site | 4 | 6 | <0.62"Ø | 0 | 0 |
| Shear | Shop | 6 | 9 | Turned | 6 | 9 |
| | Site | 5 | 7.5 | Black | 4 | 6 |
| Bearing | Shop | 12 | 18 | Turned | 12 | 18 |
| | Site | 10 | 15 | Black | 8 | 12 |
| 1948 | | | | | | |
| Tension | Shop | 5 | 7.5 | ≥0.75"Ø | 6 | 9 |
| | Site | 4 | 6 | <0.75"Ø | 5 | 7.5 |
| Shear | Shop | 6 | 9 | Turned | 6 | 9 |
| | Site | 5 | 7.5 | Black | 4 | 6 |
| Bearing | Shop | 12* | 18* | Turned | 12* | 18* |
| | Site | 10 | 15* | Black | 8 | 12* |
| 1959 | | | | | | |
| Tension | All | 6.0 | 9.0 | ≥1.12"Ø | 8.0 | 12.0 |
| | | | | ≥0.87"Ø | 7.0 | 10.5 |
| | | | | <0.87"Ø | 6.0 | 9.0 |
| Shear | Power Shop | 6.5 | 9.0 | Turned | 6.0 | 9.0 |
| | Power Site | 6.0 | 8.5 | Black | 5.0 | 7.0 |
| ** | Hand | 5.5 | 7.5 | | | |
| Bearing | Power Shop | 19.0 | 27.0 | Turned | 19.0 | 27.0 |
| | Power Site | 17.5 | 25.0 | Black | 12.5 | + |
| | Hand | 16.0 | 23.0 | | | |

* Increase by 25% when in double shear
** All values reduced by 20% when in single shear
\+ Value not given, approx 17.5 pro rata

Note: MS = Mild Steel
HT = High Tensile Steel

Table 4.5 Extract from Historical Structural Steelwork Handbook

The maximum value for permissible axial stress in compression must be amended to take into account slenderness of the sections. Table 6.7 in the Handbook is reproduced as Table 4.4, giving relevant allowable stresses for varying values of slenderness ratio. To this end the members should be analysed using BS 449 but replacing Table 17a of the BS code with Table 4.4.

It should be noted that as well as permissible stresses in pure tension or compression, BS 449 also stipulates that combined stresses due to bending, tension, shear and bearing must also be considered. In the case of the structure under consideration, which effectively acts as pin jointed trusses, only compression or tension forces are likely to predominate, hence the effects of shear etc can be ignored as they will not be significant.

With historical buildings the connections are often found to be weaker than the members themselves; particularly if bolted or riveted construction is involved. The Historical Structural Steelwork Handbook gives invaluable advice on the strengths of bolts and rivets and lists the changes in design values over the years. Table 7.1 in the Handbook giving permissible stress values in bolts and rivets is reproduced as Table 4.5 for reference. An initial check on the capacity of a bolted or riveted end connection will frequently provide the earliest indication of a structure's overall strength.

The stresses used in calculating the joint strength in mild steel black bolts (1935 and 1937) is recommended as follows, on the basis of Table 7.1 of the Historical Handbook:

Shear: 4 tons/sq inch (62 N/mm$^2$)

Bearing: 8 tons/sq inch (124 N/mm$^2$)

Tension: 5 tons/sq inch (77.5 N/mm$^2$)

## 4.3 STRUCTURAL ANALYSIS

### 4.3.1 Approach to Structural Analysis

It was not possible to locate any detailed calculations, steel certificates or record drawings concerning wartime hangars. Much of the information was therefore taken from fabricators' handbooks or historical textbooks covering that period. The appraisal of the Bellman Hangar was on the basis of BS 449 incorporating Amendment No 8, using maximum permissible stress values of 8.0 tons/sq in (123.6N/mm$^2$) for axial tension and compression.

### Main Frame

The main frame was analysed using standard structural analysis computer software as a plane truss. A trial analysis as a fixed jointed plane frame was carried out but revealed no significant differences in axial loads with only small amounts of bending in the members. The results are therefore based on plane truss analyses which are considered to give an accurate reflection of the actual behaviour of the structure.

The supports to the main frame can be considered either as a pinned footing with only one connection to the foundation unit, or as a rigid connection with each leg connected thereby forming a `couple'. The latter is a more realistic approach to the behaviour of the structure but imports greater loadings to the foundations which cannot be resisted within the normal limits of structural adequacy. In such an instance the foundation cross member may deform and will then tend to allow the structure to behave as if only one leg of each column were connected to it. This has the effect of making the structure behave as if it were truly pinned at its base. Two analyses were carried out for each height of structure and for each load case, one with both legs connected to the base, and one with one leg and a diagonal connected to the base. The latter induced less load into the foundations but caused more frame members to fail. The truth lies between these two extremes but it is recommended that for the refurbishment solutions the frame should be assessed as if only a pinned support exists at the inside face of the main columns. In this way the structural solution for the main frame will be strong enough to withstand the loads under consideration.

### Secondary Steelwork

The secondary members such as wind bracing, door head rails, purlins and sheeting rails were analysed using standard means. These members, apart from the door head units, consist of mainly pressed metal U sections in varying states of repair. A similar approach to calculating their permissible stresses was used to that for the main frame.

### Foundations

The foundations were analysed as simply supported beams spanning between two pads with an offset point load from the inside leg of the column.

## 4.3.2 Findings of the Structural Analysis

### Main Frame

The main frame was analysed for two heights and for three wind speeds these being 45 m/s, 48 m/s and 52 m/s. The following tables are on the basis of the conservative assumption of pinned bases for the dead, imposed and wind load cases.

In discussing the results it should be noted that BS 449 assumes an elastic behaviour of the structure and uses a factor of safety of 1.7. Therefore, a structure may be overstressed theoretically and may deflect excessively but it will not actually yield or collapse until its weakest component is loaded in excess of 170% of its safe working load. Within this document the term overstressed is used for any component found to have a stress level of between 100% to 170% of its design working stress. The term yield refers to any member found to have a stress level in excess of 170% of its design working stress and which theoretically could lead to crippling and actual collapse of structure. Hence a failed member or joint refers to a situation of overstress and in some cases yield too.

| Frame Members | Wind 45 m/s | | Wind 48 m/s | | Wind 52 m/s | |
|---|---|---|---|---|---|---|
| | 2 Units | 3 Units | 2 Units | 3 Units | 2 Units | 3 Units |
| Main Chords | 17% | 22% | 17% | 22% | 20% | 32% |
| Diagonals | 64% | 59% | 64% | 59% | 64% | 75% |
| Eaves Units | 54% | 62% | 54% | 62% | 54% | 85% |

Table 4.6 % of Failed Members (Under Dead, Imposed and Wind Load)

In addition to members failing, almost entirely in compression, the bolted joints between units failed.

| Height | Wind | | |
|---|---|---|---|
| | 45 m/s | 48 m/s | 52 m/s |
| 2 Units | 67% | 80% | 80% |
| 3 Units | 82% | 82% | 82% |

Table 4.7 % of Failed Joints (Under Dead, Imposed and Wind Load)

A graphical illustration of the failed members and joints is shown in Figures 4.8 and 4.9. The results showed that a large proportion of the structure is overstressed. The structure remained reasonably stable under dead load, but when the imposed load is applied members become stressed up to 120% and joints by up to 150% of their safe working load. It was discovered that the structure cannot accept more than approximately 0.2kN/m² of superimposed load which equates to a depth of 100mm of snow, without becoming overstressed.

PAGE LEFT INTENTIONALLY BLANK

FAILED JOINTS AND MEMBERS
(Under Dead, Imposed and Wind Loads)

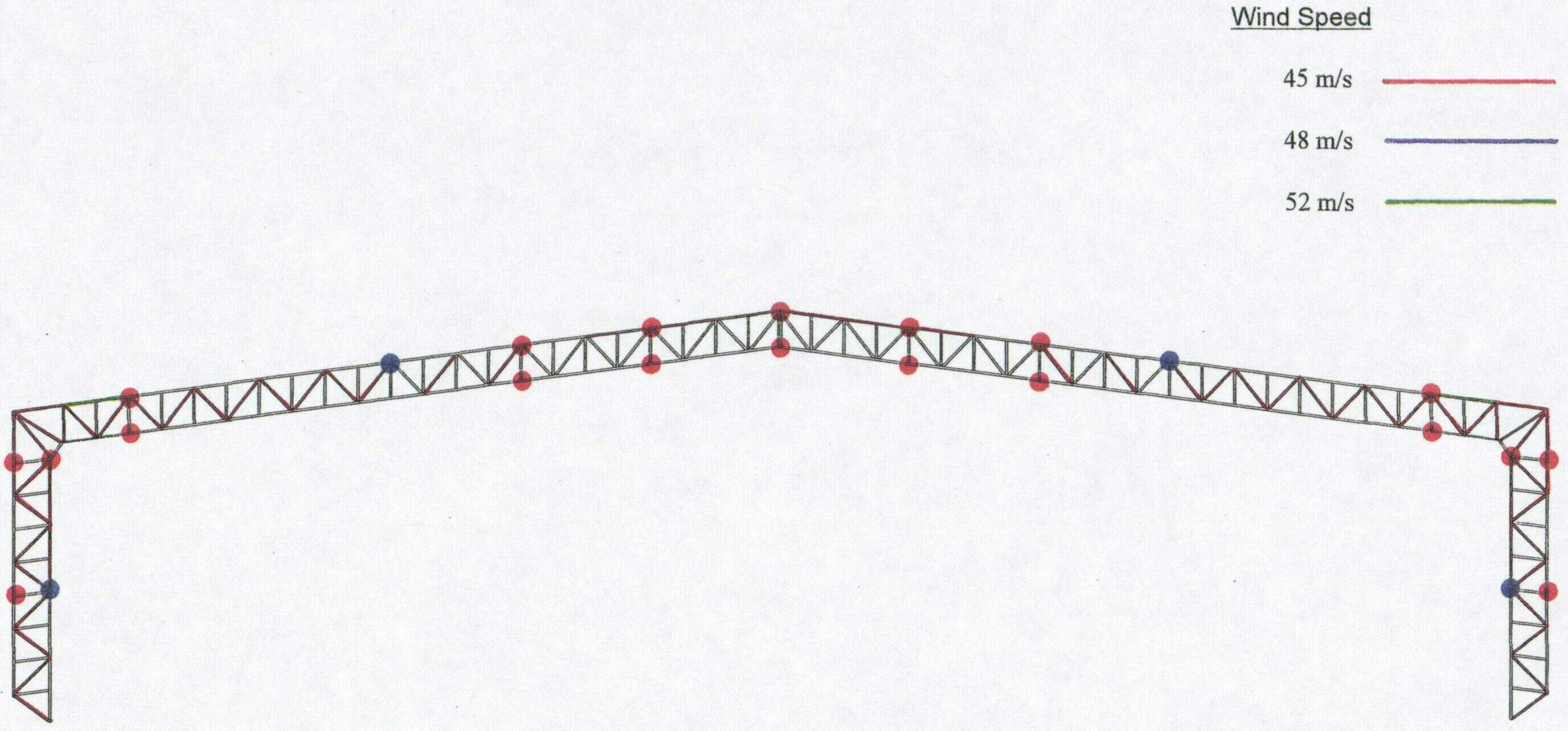



Figure 4.8 2 Unit High Bellman Hangar

(NB: Failures shown are additive)

FAILED JOINTS AND MEMBERS
(Under Dead, Imposed and Wind Loads)

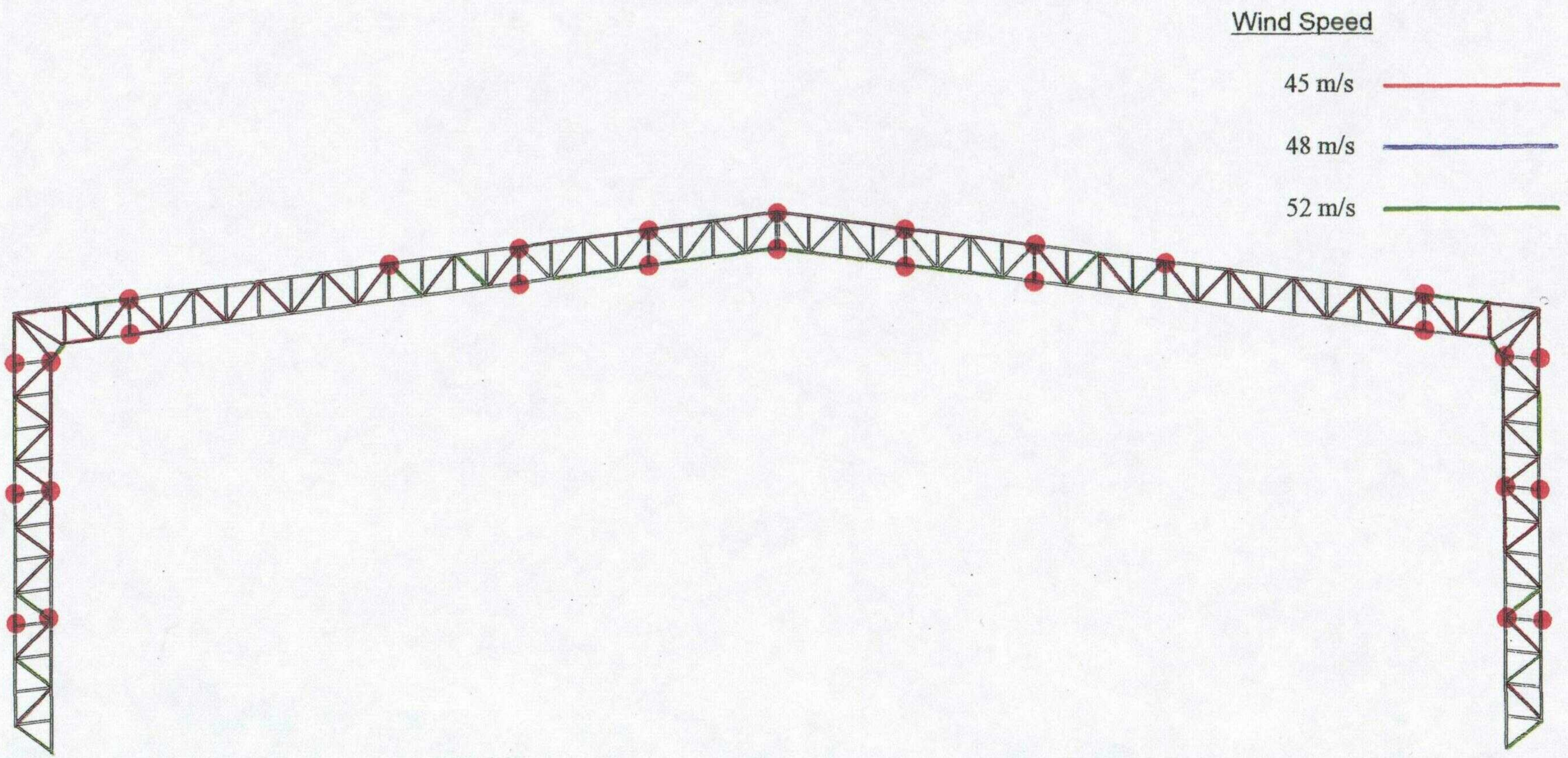



Figure 4.9 3 Unit High Bellman Hangar

(NB: Failures shown are additive)

The above loads do not take into account induced loading from the bracing systems which may increase the number of members to fail.

When considering dead and wind loading alone, the following members are overstressed.

| Wind Speed | Wind 45 m/s | | Wind 48 m/s | | Wind 52 m/s | |
|---|---|---|---|---|---|---|
| Height | 2 Units | 3 Units | 2 Units | 3 Units | 2 Units | 3 Units |
| Main Chords | 0% | 0% | 0% | 2% | 1%+ | 5% |
| Diagonals | 58% | 47% | 64% | 59% | 64% | 75% |
| Eaves Units | 0% | 25%** | 8%* | 50% | 54% | 83% |

Table 4.10 % of Failed Members (Under Dead and Wind Load)

+ Members overstressed by 14% only
* Members overstressed by 3% only
** Members overstressed by 8% only

For the 2 unit high hangar, apart from the diagonal members which are stressed by up to 127%, 164% and 226% of their safe working load at wind speeds of 45 m/s, 48 m/s and 52 m/s respectively, the remainder of the frame can withstand dead and wind forces alone for wind speeds of up to 48 m/s. Above this the eaves units are likely to fail. For the 3 unit high Bellman, at wind speeds up to 45 m/s, the diagonals fail but the remainder of the frame remains reasonably sound. The foregoing neglects the effects of the loading system upon the joints which require upgrading even for dead and wind loads alone.

To summarise, the main frame can withstand dead loads and, although heavily overstressed, it can withstand a snow load of 0.6kN/m$^2$ without yielding. For wind loading, with dominant openings, the frame is likely to exceed the yield condition and be crippled in the diagonals and the eaves units depending upon wind speed. The joints require strengthening for all load cases.

### Secondary Members

The pressed metal purlins are found to be satisfactory under dead load but to fail at dead plus imposed loads. They are found to be able to support a total of 0.2kN/m$^2$ imposed load equating to a snow depth of 100mm. For the wind load cases, the purlins are stressed to between 137% and 201% of their safe working load indicating that in wind speeds over 48 m/s they would be likely to yield if a dominant opening were present.

The sheeting rails are found to be adequate for dead loading but to fail in any significant wind load even with the hangar doors closed. It can only be assumed that the sheeting rails have remained in place to date by benefiting from the effects of skin tension in the cladding.

The gable end and door head support beams are found to be satisfactory except for the lower stays giving lateral support to the inside face of the gable columns. This arrangement is unsatisfactory as the stays induce axial load and bending into an already overstressed sheeting rail.

The roof bracing is unsuitable as the purlins which form part of this system are already overstressed due to bending from the vertical load. In addition several of the diagonal bracing members fail as shown below.

| Height | Wind | |
|---|---|---|
| | 45 m/s | 52 m/s |
| 2 Units | 0 % | 17 % |
| 3 Units | 50 % | 83 % |

Table 4.11 % of Failed Diagonal Roof Bracing Members

The side sway bracing is similarly unsuitable as it relies in part on already overloaded members. The majority of the diagonal members are also overstressed as shown below.

| Height | Wind | |
|---|---|---|
| | 45 m/s | 52 m/s |
| 2 Units | 33 % | 100 % |
| 3 Units | 100 % | 100 % |

Table 4.12 % of Failed Sway Bracing Members

To summarise, when considered against the poor condition of many of the purlins and sheeting rails, it can be seen that the majority of the pressed metal components of the purlins, sheeting rail and wind bracing systems are heavily overstressed and in need of strengthening or replacement.

## Foundations

The foundations were analysed as if the structure is pinned to the "back to back" channels by one connection only at the inside of each column. The capacity of the foundation is limited by the bending capacity of the cross beam for downward thrust, and by the resistance to uplift available. The latter can only be notional since there is no evidence to show that proper holding down bolts or concrete pads were used. In practice any resistance will be provided by the concrete floor slab lying over the foundation arrangement and the dead weight of any backfill on the outer pad.

The bending capacity of the foundation unit is exceeded in all but the dead load case for each height of structure. As such the foundation units will require strengthening. In addition, they suffer from uplift under certain wind loads and extra dead load must be provided in the form of kentledge or mass concrete to give sufficient resistance.

PAGE LEFT INTENTIONALLY BLANK

# 5.0 OPERATIONAL REQUIREMENTS

The Bellman hangar is subject to various operational requirements, some in the form of restrictions due to concerns about its structural safety and some in connection with hangar doors and periodic professional appraisal and inspection of hangar.

## 5.1 OPERATING RESTRICTIONS

There should be no doubt that the findings of the structural appraisal of the Bellman hangar are of serious concern. Precautionary measures must therefore be taken by all those engaged in duties connected with a Bellman hangar for reasons of safety and to counter the potential risk of its collapse.

DWS Technical Bulletin 39/94: Hangars - Safety of Structure - Recommendations for Users During Adverse Weather Conditions was issued in August 1994, for use in connection with any type of wartime hangar. The TB advised that the hangar is placed under observation when snow build up on the roof exceeded 200mm and that the hangar doors are kept closed in wind speeds exceeding 27 m/s (60 mph) in gusts.

The results of the in-depth study of the Bellman hangar warranted a mandatory safety notice to be issued specifically for this hangar type. This notice was given in DWS Technical Bulletin 55/94: Hangars - Bellman Type - Safety Precautions - Recommendations for Users During Adverse Weather Conditions, dated December 1994. The requirements of the Safety notice must be observed at all times and are re-stated below. The warnings are given in terms of limiting environmental criteria. The likelihood and frequency of these criteria being reached will vary between locations and therefore their implications will vary on a site by site basis.

> During Snowfall:
>
> When freshly fallen snow settles to a depth of 100mm on the roof of the hangar the Property Manager shall advise the Commanding Officer that all personnel must be instructed to leave the hangar and all entrances to the hangar should be securely closed.
>
> During High Winds:
>
> When wind speeds are expected to reach gusts of 27 m/s (60 mph) all main doors are to be closed. When wind speeds are expected to reach gusts of 36 m/s (80 mph) the Property Manager shall advise the Commanding Officer that all personnel must be instructed to leave the hangar and all entrances to the hangar should be securely closed.

Emergency Action Plan:

For each hangar on the MOD estate, the Property Manager is to agree an Emergency Action Plan with the Commanding Officer, the EWC and the WSM. The Emergency Action Plan should give details of responsibilities of each MOD staff, the EWC and the WSM, and their respective actions required to be taken during adverse weather conditions.

Action Following Adverse Weather:

When adverse weather conditions have occurred, personnel must not be allowed back into the hangar until the hangar has been inspected by the EWC and has been declared safe for the resumption of normal operations.

For ease of understanding the operating restrictions a flow chart is given at Figure 5.1 indicating steps that need to be taken. The flow chart is not an action plan to be followed during adverse weather conditions. For each MOD estate with a Bellman hangar an Emergency Action Plan should be devised as explained above. The value of stores and aircraft must also be assessed in order to decide if their removal is necessary.

The operating restrictions must not be lifted for any Bellman hangar until it has been appraised and cleared by a competent Chartered Civil or Structural Engineer experienced in this type of work.

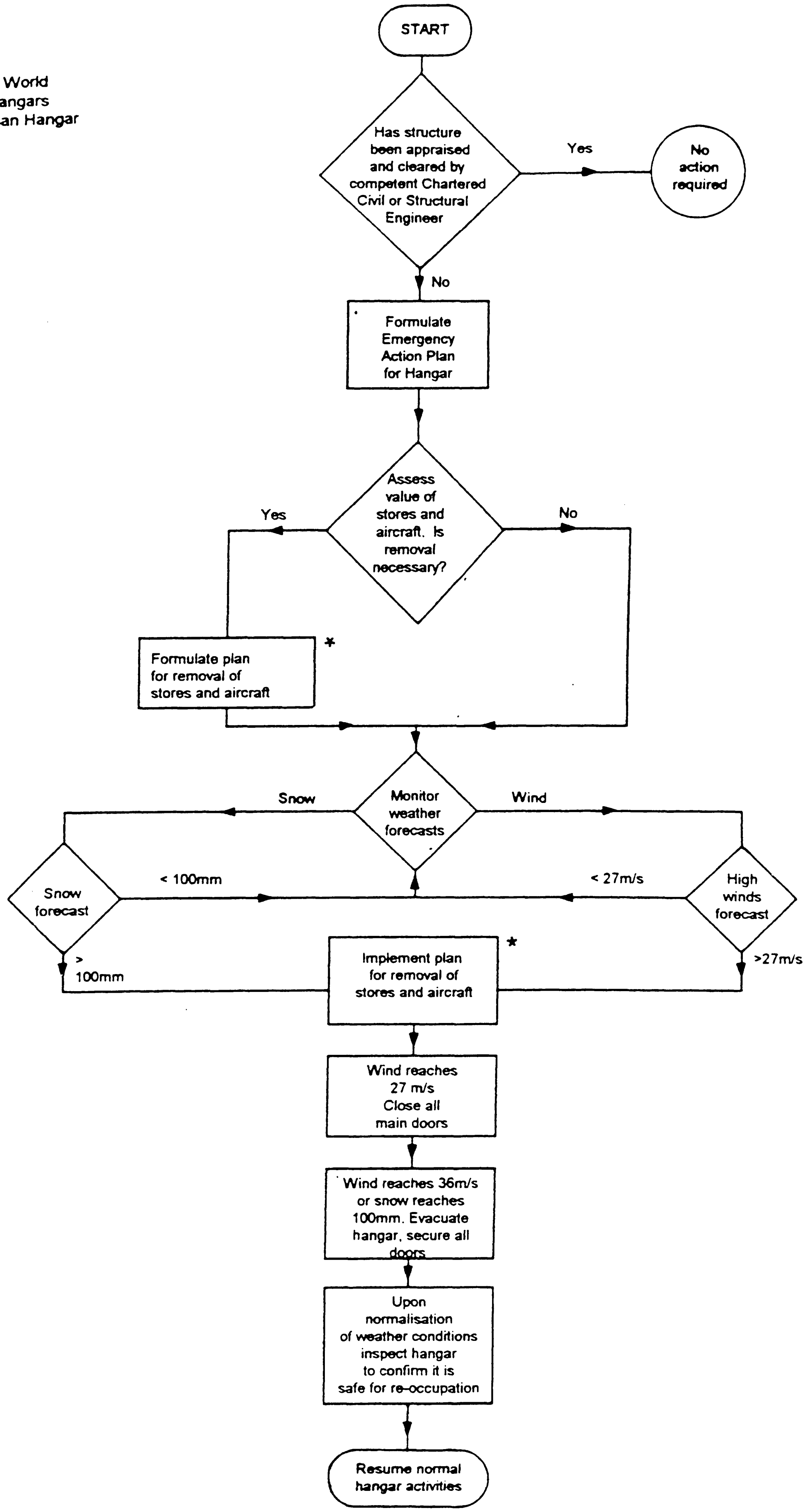



Figure 5.1 Operating Restrictions During Adverse Weather

## 5.2 HANGAR DOORS

In August 1994 DWS issued Technical Bulletin 40/94: "Hangars and Industrial Buildings - Inspection, Maintenance, Adjustment and Use of Large Sliding and Folding Doors". This TB is particularly relevant to the Bellman hangar doors, defining among other items the roles and responsibilities of the User, the EWC, the WSM and the Project Manager in connection with activities related to hangar doors. Information on the safe use and maintenance of doors and their fixtures was given for the benefit of all those engaged in duties connected with hangar doors.

### 5.2.1 Statutory Requirements

a. Health and Safety

To comply with the Health & Safety at Work etc Act 1974 and its subordinate legislation, an assessment of the risks associated with the inspection, maintenance, adjustment and use of doors must be carried out, all hazards identified and any significant risks noted.

Those carrying out work in connection with doors must be made aware of the hazards (eg access to and working height) and should provide written safe systems of work. Only competent persons suitably trained on any equipment to be used and familiar with the safe system of work should be engaged for working at height.

The safe system of work should show how it is intended to gain access to the various parts of the doors and associated fixtures and fittings, also any safety precautions necessary to reduce or eliminate the risks to their employees.

As part of the Property Management system, records should be kept of the inspection and of the wear on doors and their components and it is recommended that an individual check list be drawn up.

### 5.2.2 MOD Requirements

a. DWS Specification 005

The current DWS Specification 005 Issue No 002, June 92: Property Management of the Defence Estate specifies mandatory requirements for the WSM and EWC. It is important to note that reference is made to the latest edition of DWS Specification 005. The mandatory requirements are as follows:

(i) Maintenance, inspection and adjustment of doors every 6 months by the WSM as stipulated in Schedule 6B Task No 052 of the Specification.

(ii) Regular inspections by EWC as stipulated in Schedule 6A Task No 051 of the Specification. The intervals are every 6 months, extended to every 12 months for Ascension Islands and Falkland Islands.

(iii) At the time of inspection, the EWC is to arrange for the WSM and WSM Specialist Maintenance Contractor to be available for repairs, as per tasks 051 and 052.

b. Operation of Doors - User Tasks

The User should be responsible for the day to day operation of the doors. He must ensure that:

(i) Bottom tracks are kept free of debris.

(ii) Excessive force is not used to open, close or move doors. Doors which are difficult to move may be obstructed or in need of repair.

(iii) In the event that doors cannot be opened or closed freely or appear out of alignment, the PROM is informed of the situation as a matter of urgency.

(iv) Tractors or other Mechanical Handling Equipment (MHE) are not used to operate doors, as they could force the wheels off the tracks. In addition , they could damage end stops or the carriages and wheel mechanisms.

c. Maintenance of Doors - WSM Tasks

(i) The maintenance tasks must include cleaning and lubrication of wheels, rollers, guides, runners, springs, winding gear, ropes and chains. Where available the manufacturer's instructions must be followed.

(ii) Doors must be checked for correct opening and closing and left in correct working order following any maintenance work.

d. Inspection of Doors - EWC Tasks

(i) Recommend inspection of doors, particularly the vulnerable parts at more frequent intervals where certain circumstances necessitate, for example where:

- Doors are subjected to high use or susceptible to damage.

- The environment is hostile (eg high winds or high corrosion rate).

- This is stipulated by the door manufacturer.

(ii) The following list covers checks and items for inspection. The list below is not exhaustive as the EWC may find it necessary to cover additional checks:

- Alignment and condition of upper and lower tracks and guides. Uneven wear on wheels. Doors designed to be top supported are not to bear on the bottom guides and similarly doors designed to be supported from the bottom are not to be supported by top guide wheels.

- Condition of wheels, rollers, guides, runners and springs. (Metallic parts such as wheels and rollers are to be "rung" with a hammer as a means of detecting cracks).

- Bearings, circlips and bearing retaining nuts. (Excess play in bearings should be noted and more detailed examination carried out where appropriate. This may involve removal and dis-assembly of the bearing).

- Condition of door stops and buffers. (Deformed or cracked items should be replaced and metallic stops should be rung. Particular attention should be paid to upper stops, checking tightness of bolts and soundness of welds).

- State of door frames and sheeting and the maintenance of adequate clearance between door leaves.

- Condition of winding gear, ropes and chains. (The condition and existence of detachable winding handles should also be checked).

- Ensure that the doors are prevented from lifting off the top tracks and moving sideways.

- Ensure that damaged and loosened components (eg wheels, stops, etc) cannot fall from top tracks and cause injury.

- Correct opening and closing of doors after every inspection.

e. Modifications to Doors

(i) The User is not permitted to modify doors as this could be detrimental to their operation. For example:

- Additions of any kind must not be made to doors as this could cause eccentricity or overloading on the door supports (eg brackets, insulation, additional linings, etc).

- Doors which are designed to be separated into a number of leaves must not have their leaves connected together to facilitate opening and closing.

(ii) Proposals for modifications can be made where there is an advantage in improved safety or functioning of the doors. For example:

- To prevent sideways movement of doors when they become lifted from top tracks.

- Replacing cast iron with mild steel wheels which have wider flanges.

- Introduction of compression springs, where none exist, in order to keep the wheels in contact with the bottom track.

(iii) The EWC must inform the PROM of any proposals for modifications to hangar doors and the reasons with estimated costs why this is considered to be necessary. Following the PROM's instruction to proceed, the WSM must arrange for a competent, suitably qualified engineer to design the modifications. This must include the preparation of full documentation including calculations, drawings, specifications and a method statement. In certain circumstances to comply with the Building Regulation, approval will have to be obtained and the design checked by an independent person as required by Schedule 7 of DWS Specification 005.

f. Project Handover - Project Manager Tasks

(i) At handover of a project involving hangar doors, the Project Manager is to ensure that the doors are left in safe working order without any significant snagging defects outstanding.

(ii) As part of the Operations and Maintenance manual, all available details of the door should be included such as drawings, specifications, calculations and availability of replacement parts. Any manufacturer's recommendations or guarantees relating to maintenance or inspection is to be passed via the PROM, to the EWC/WSM, particularly where this includes maintenance to be carried out by the manufacturer as part of the defects liability period or where the frequency of inspections exceed those of DWS Specification 005.

## 5.3 PROFESSIONAL APPRAISAL AND TECHNICAL INSPECTION

The EWC must carry out a Professional Appraisal of the hangar at 5 yearly intervals and a Technical Inspection at 2 yearly intervals, in accordance with Tasks 582 and 584 of DWS Specification 005. The above tasks are currently being reviewed by DWS and a revised specification is expected to be issued later this year.

# PAGE LEFT INTENTIONALLY BLANK

# 6.0 REFURBISHMENT WORKS

## 6.1 ROOF AND WALL CLADDING

One of the most common works items during major refurbishment of a hangar is renewal of roof and wall cladding. This could be for various reasons, e.g. unsatisfactory or irreparable water proofing, better thermal insulation for energy conservation as per MOD policy, uneconomical repair and maintenance costs, etc.

Roof cladding as originally used on Bellman hangars was in the form of corrugated galvanised iron sheeting. Being a light-weight hangar, re-cladding will have a major effect on the Bellman's structural behaviour, for example:

a. Change in permeability of the cladding has major effects of loading transferred to the hangar structure.

b. Change in fixings and cladding stiffness has major effects on the structural restraint that cladding provides to the hangar.

c. Change in dead load; an increased weight of cladding will adversely affect the steel frame, whereas reduced weight cladding will increase the likelihood of an "uplift" problem.

The provision of thermal insulation in itself for refurbishment works will not fall under the control of Building Regulations. However, total re-cladding of a hangar may be considered to be a "material alteration" if it adversely affects the existing building in relation to compliance with requirements for structure. Further information on the application of Building Regulations is given in Chapter 9.1.

As a general rule, Building Regulations require the maximum 'U' value for roof and wall cladding to be 0.45 $W/m^2K$ except where a low level of heating output not exceeding 50 watts per square metre of floor area is installed, when there is no requirement for insulation. It is recommended that, as Building Regulations requirements are minimum standards, they should be applied to that element undergoing refurbishment. This would also support MOD policy on energy conservation.

The Building Regulations for England and Wales Part L has been revised and the new standard will take effect on 1 July 1995. It has a higher requirement than the current document in relation to glazed areas, doors and roofs, and it is advisable that this later standard is followed.

## 6.2 STRENGTHENING OF STRUCTURE

The appraisal of the Bellman Hangar showed that it is deficient in several areas when compared against current standards and regulations. If major refurbishment is considered the main frame will require strengthening. the purlins and sheeting rails replacing. new bracing members installed. and the foundations strengthening and enlarging. The following suggestions are developed for costing purposes only and should not be considered as standard or ideal solutions. Steelwork designers and contractors may have alternative economical solutions and these should be duly considered.

### 6.2.1 Main Frame

The main frame consists of a pin jointed truss to all intents and purposes, hence it can be strengthened by adding cross-sectional area in the form of welding plates to those members which fail and by strengthening weak joints. After consideration of the extent of failure and its nature it is thought prudent to plate up the main chords and replace the internal members; the joints require welding to replace the inadequate bolts now in use; the eaves units are heavily overstressed. An alternative would be to leave them in situ and replace some members whilst plating others. The cost of either option will not affect the overall cost significantly. Some typical details of proposals for strengthening the standard portal frame unit are given below.

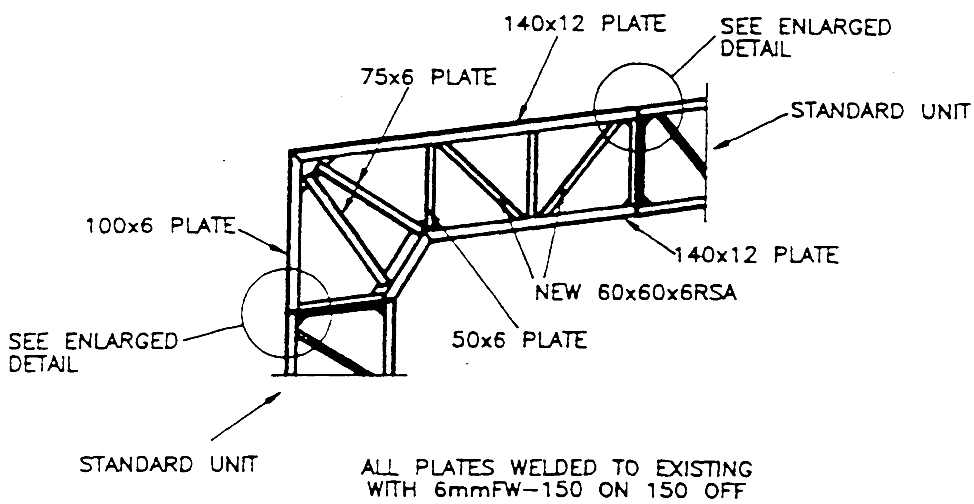



Figure 6.1 Corner Unit

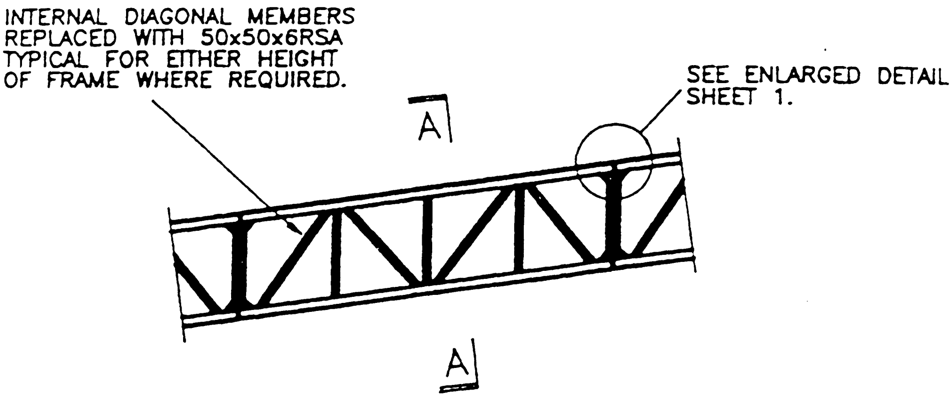



Figure 6.2 Standard Unit (Sloping)

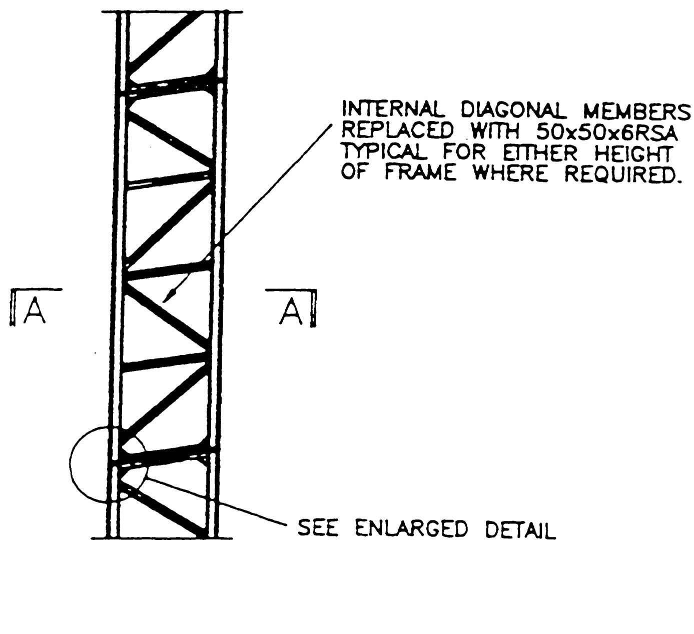



Figure 6.3 Standard Unit (Vertical)

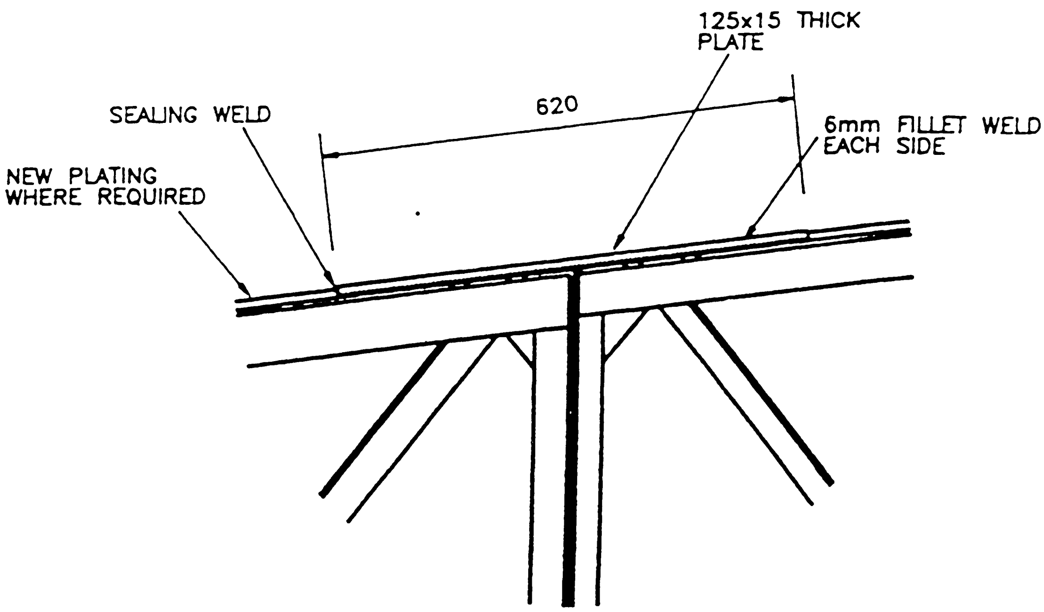



Figure 6.4 Joint Detail

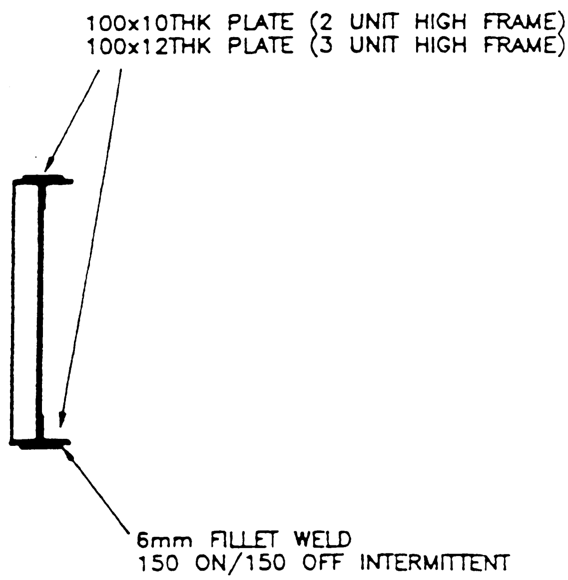



Figure 6.5 Section A-A

### 6.2.2 Secondary Steelwork

#### Purlins and Sheeting Rails

The purlins and side rails are overstressed due to dead plus imposed loads and due to dead plus wind load. Three options exist as regards rectifying this situation, these being: propping, inserting extra rows of purlins and rails and installation of a new system of cold rolled elements. The two former options, as well as being labour intensive, will also rely on the continued use of the existing purlins and rails. Evidence gained during site inspections showed many of these to be corroded. It is thought that these two options will be compromised by this fact and that the third option is the most prudent to choose. Therefore the option of installing a new system is likely to be the most cost effective as its expected life will be in excess of any of the refurbishment options.

#### Bracing Systems

The hangars are braced by use of cold rolled sections similar to the purlins and sheeting rails. They have been found to be inadequate for this purpose and should be removed and replaced. Conventional circular hollow section ties could then be inserted.

### 6.2.3 Foundations

The examination of the structures showed that problems exist with uplift of the structure due to wind loads when large openings exist. In order to allow the use of the hangars in all wind loading conditions it is necessary to add extra dead load to the foundations. The existing foundations consist of metal cross beams supported on two corrugated metal pads, one at each end. The pads have been spiked to the ground and may rest on hardcore, railway sleepers or on concrete blinding. In some special cases they may rest on conventional concrete pads.

In order to provide extra dead weight the foundations should be excavated and a new foundation cast up to ground level, encompassing the existing metal cross beam, and being large enough to provide sufficient kentledge for the structure. This will also serve to resolve the problem of bending failure in the cross beam.

## 6.3 DOORS

During major refurbishment works covering renewal of roof and wall cladding, it would be reasonable to renew cladding on doors. Refurbishment works can also involve other items such as structural repairs to the door frame where necessary, replacement or repair of the tracks, guides, wheels, etc.

Existing cladding provides a stiffening function to doors whereas re-cladding with a light-weight material may not provide the same degree of support and could result in unsatisfactory door performance. Replacing cladding with a composite material may not be practicable as the cladding will be too thick to permit doors passing over one another.

If a hangar is no longer in use as an aircraft hangar, the large sliding doors may be permanently welded or fixed to the gable-end structural steelwork. Smaller doors could then be re-introduced within the fixed large doors. It should be ensured that both design and modification works are fit for the purpose, such that the modifications remain permanent for the remainder life of the building. If the doors continue to be supported in full or in part by mechanical fixtures such as wheels, tracks, rollers, rails, etc then the statutory and MOD requirements for maintenance and inspection as discussed in Chapter 5.2 will remain obligatory.

## 6.4 FLOORS

The repair, upgrade or renewal of a hangar floor during refurbishment would depend on the particular site, i.e. the condition of the floor, its functional requirements and most importantly economic considerations.

Repairs to floors and application of numerous types of floor toppings and finishes is now commonly considered a specialist works item, carried out by specialist contractors. Depending on particular problems with a floor, a contractor specialising in such works should be engaged. The specialist contractor or designer should survey the floor, carry out tests, diagnose any problems and their causes and recommend solutions.

In view of the above and the wide range of problems associated with a hangar floor, recommendations are not made in this Functional Standard for specific solutions. As a guide however, the following is a list of some of the items which can be of concern to a PROM or Project Sponsor:

Load capacity
Flatness
Aesthetics (colour, appearance)
Hardness
Dust proof
Abrasion resistance
Chemical resistance (impermeable to oils and fluids)
Waterproof
Slip resistance
Cracking
Spalling
Osmosis
Joints (uneven joints, requirement for seamless floor, joint sealants, etc)
FOD (Foreign object damage)

Most of the above characteristics can be met by laying a new screed and coating, on the existing slab unless the sub base or soil conditions are such that the specialist contractor advises a total renewal of the floor.

Defence Works Functional Standard 06: Guide to Airfield Pavement Maintenance published by HMSO ISBN 0 11 772730 X contains advice on concrete floors and it is suggested that reference is made to this document.

## 6.5 DRAINAGE

Rainwater gutters and downpipes must be inspected for leaks and renewed if necessary. If slate or other cement-based roof cladding is being replaced by metal clad sheeting, then faster run-offs will be expected. Hence larger capacity guttering and downpipes may be required.

## 6.6 ROOFLIGHTS, LIGHTING AND HEATING

If natural lighting is required, then this should be specified by the user in full knowledge of the extra initial and running costs this may incur. Any natural light system should be professionally designed to give a uniform distribution of light to a minimum daylight factor of 7%. This will require rooflights equivalent to approximately 10% of the floor area evenly distributed throughout the roof. If natural daylight is not a user requirement then it is recommended that rooflights are not installed during refurbishment.

With modern high efficiency lighting units any extra energy which will be required to light the building will be compensated by the increased thermal efficiency of the hangar without rooflights. Disadvantages of rooflights include:

a. high initial cost over cladding.

b. high cleaning and maintenance costs.

c. more frequent replacement than cladding.

d. can cause glare within the hangar.

e. lower thermal resistance and prone to condensation drip.

f. difficult to achieve current or future blackout requirement.

Guidance on suitable levels of lighting is available in the Lighting Guide No 1 "The Industrial Environment" 1989, Chartered Institute of Building Services Engineers (CIBSE).

The requirements for heating are given in the appropriate Scales in the Services Accommodation Code, JSP 315. They should be checked and agreed with the PROM or Project Sponsor, depending on the specific use of a hangar. Minimum levels of heating are to be provided in compliance with the Health & Safety Regulations.

## 6.7 PHYSICAL SECURITY

During any refurbishment project, the Project Sponsor must give consideration to physical security. The Secure Building Specification for Industrial Type Buildings as approved by MOD Security Directorates, reference D/DSy(A)/121/1/2 dated 3 February 1994 should be followed. The full specification is available from:

DOE Special Services Group
Security Advisory Branch
St Christopher House
Southwark Street
London
SE1 0TE

Tel: 0171 921 4928
Fax: 0171 921 3802

Guidance to Project Sponsors, PROMs and security officers on the methods of obtaining security assistance and advice for works services is given in DCI GEN 125/94.

During recladding works, it is recommended that a dado wall of 2.7m minimum height above ground level with sheet cladding above is constructed. The wall should be of masonry cavity construction with insulation between two skins of minimum 100mm thick brickwork or blockwork. If insulated metal cladding is used as the outer skin, the minimum thickness of the internal skin should be 150mm. If the hangar is used to store large classified equipment or vehicles, then the minimum height of masonry wall will be increased to 3.15m above ground level. In this situation the internal skin should be minimum 150mm thick or 180mm thick if the outer skin is insulated metal cladding.

Figures 6.6, 6.7 and 6.8 give illustrations of typical details of the dado wall. The wall height and thicknesses shown are minimum. The wall should be designed for structural stability depending upon site and environmental conditions. For example, it may be useful to consider masonry buttresses or tie beams at the top of the wall. Suitable details to prevent the penetration of rain should follow the principles given in Building Research Establishment Report 143: Thermal insulation: avoiding risks 1989 ISBN 0 05125 3830 (BRE).

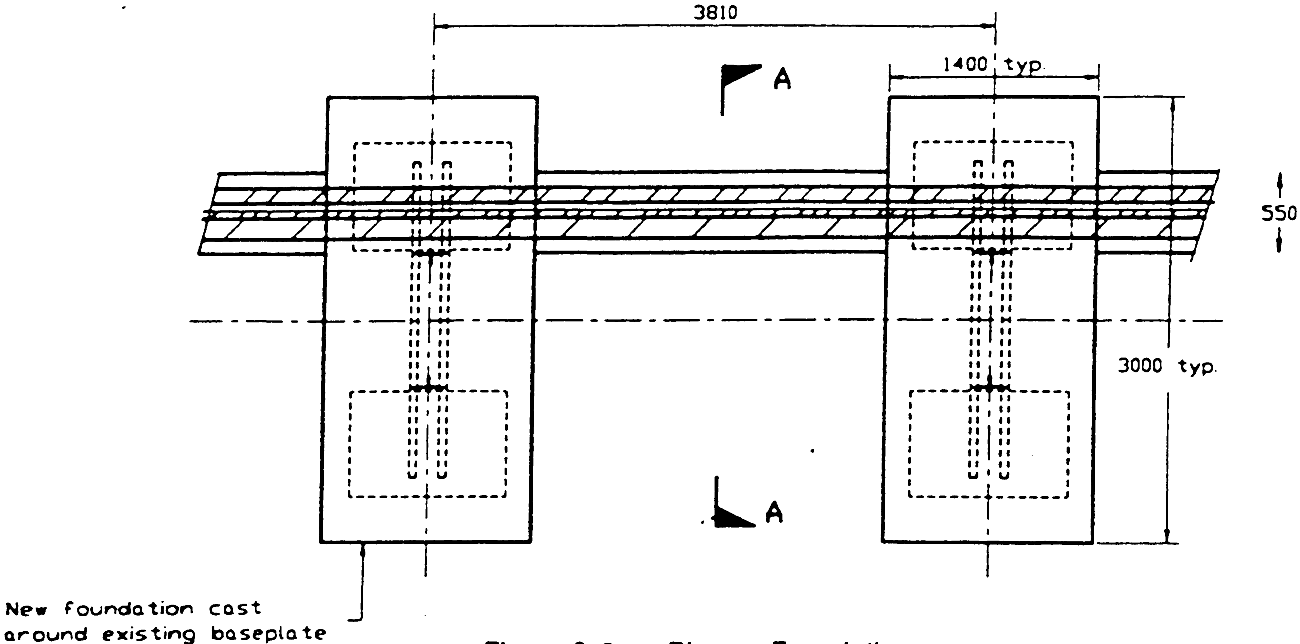



Figure 6.6 Plan on Foundations

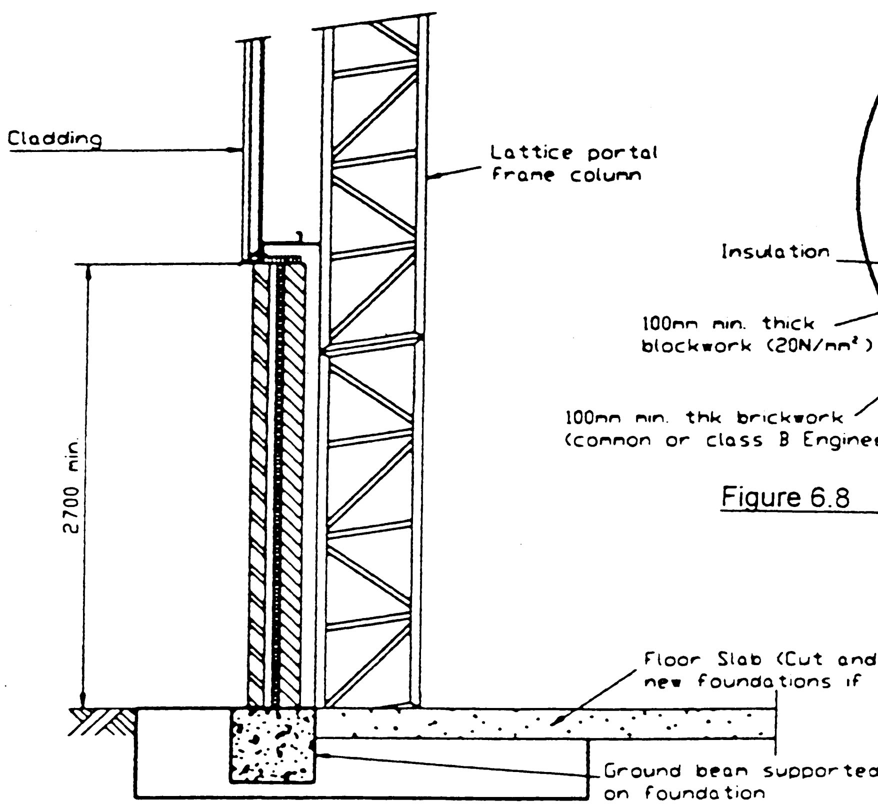



Figure 6.7 Section A-A

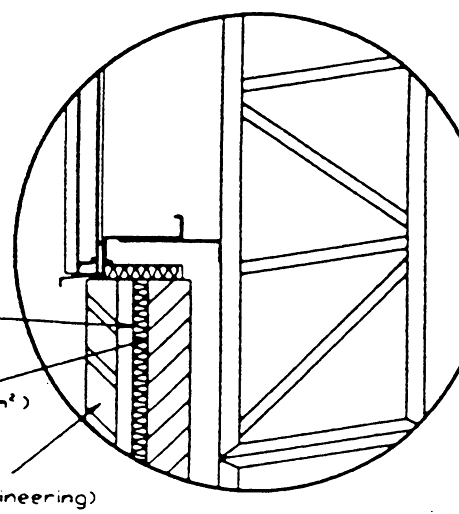



Figure 6.8 Enlarged Detail at Top of Wall

# PAGE LEFT INTENTIONALLY BLANK

# 7.0 NEW BUILD ALTERNATIVE

An option study on any project should include a new build alternative besides the refurbishment option. A new build hangar as a "like for like" alternative was considered in order to perceive its structural form using modern higher quality steelwork and also to help give an estimate of its costs. In reality, the replacement structure is likely to be different in view of a Project Sponsor's current operational needs and use of different physical dimensions to give greater economy in construction.

The latest editions of all relevant British Standards should be used in the design of a new hangar. As part of the study a new steel portal framed building was analysed using BS 5950 design principles and current loading codes. The frame layout was matched as near as possible to the existing structure. The frame centres however were increased to approx 6.0m using 10 frames in total. Hence the advantage of modern cladding support systems was taken. The clear heights at the eaves below the haunch and the rafter heights were maintained.

The main members for the portal frame and foundation sizes were calculated as follows:

| Wind Speed | Columns | Rafters | Foundations |
|---|---|---|---|
| 45 m/s | 533 x 210 x 92 UB | 457 x 191 x 74 UB | 2.25 x 2.5 x 1m |
| 48 m/s | 533 x 210 x 92 UB | 457 x 191 x 74 UB | 2.6 x 2.6 x 1m |
| 52 m/s | 533 x 210 x 92 UB | 610 x 229 x 125 UB | 2.8 x 2.8 x 1m |

Table 7.1 Steelwork and Foundation Sizes of New Build Hangar

For a new hangar, the designer must ensure that MOD policy and specifications for a building of this kind is complied. As a reference, the list below states MOD publications for use in the design and construction of a new hangar. The latest revisions to these publications should be checked.

- Air Publication (AP) 3384 Vol 1 (4th Edition) - Safeguarding Criteria and Movement Area Specifications for Permanent Aerodromes.

- MOD Publication JSP 318A - Military Air Traffic Services (Chapter 23 + for AGL) (Movement Area Floodlighting).

- Relevant Sections of PSA's M&E Guide (MEG) and CU (M&E) Drawings.

- AP 100D-20: Precautions Against Electric Shock in Electric Hazard Areas of Electrical and Electronic Maintenance Facilities.

- AP 113A - 0201-1 : Earthing of Aircraft and Ground Support Equipment.

- PSA Publication : A Guide to Airfield Pavement Design and Evaluation (ISBN 0 86177 127 3).

- Fire Standard D6 : "Fire Alarm Systems - Automatically Operated", April 1987.

- Fire Standard E4 : "Office Buildings", April 1987.

- Fire Standard E9 : "Garages, Vehicle Workshops, Vehicle Storage and Car Parks in Buildings", April 1987.

- Fire Standard E10 : "Aircraft Hangars", November 1993.

- Fire Standard E11 : "Storage Premises", April 1987.

# 8.0 COST COMPARISONS

No option for a solution can be given full consideration without some idea of cost implications. Technical solutions on their own to overcome a problem do not carry any merit unless they can be proven to be economically viable.

Budget cost estimates are therefore given in this chapter for the basic work items in connection with a typical Bellman hangar, and a new build alternative. All costs are base estimates, in that they are 'raw' costs without inclusion of risk additions, preliminaries, VAT or professional fees. A site specific investment appraisal of the various options should take all such factors into account.

The base estimates in the Tables 8.1 and 8.2 are on the basis of 2Q 1994. All estimates will require validation for a particular project and updating to current price levels. They provide a rough guide for budgeting and comparison purposes.

| Work Item | 45 m/s | | 48 m/s | | 52 m/s | |
|---|---|---|---|---|---|---|
| | 2 unit high | 3 unit high | 2 unit high | 3 unit high | 2 unit high | 3 unit high |
| Strip Cladding | 19,298 | 22,305 | 19,298 | 22,305 | 19,298 | 22,305 |
| Remove Purlins & Rails | 3,785 | 4,907 | 3,785 | 4,907 | 3,785 | 4,907 |
| Strengthening | 42,626 | 52,417 | 43,052 | 52,417 | 45,077 | 65,490 |
| Fix New Purlins & Rails | 14,724 | 16,004 | 14,724 | 16,004 | 14,724 | 16,004 |
| Reclad | 105,600 | 117,360 | 105,600 | 117,360 | 105,600 | 117,360 |
| Cast New Foundations | 10,742 | 12,631 | 12,250 | 15,124 | 14,911 | 18,108 |
| Method Related Charges | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Painting | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| Sway Bracing | 2,980 | 3,357 | 2,980 | 3,357 | 2,980 | 3,357 |
| Refurbish Doors | 22,608 | 31,424 | 22,608 | 31,424 | 22,608 | 31,424 |
| Services | 50,000 | 50,000 | 50,000 | 50,000 | 50,000 | 50,000 |
| TOTAL | 307,363 | 345,405 | 309,297 | 347,898 | 313,983 | 363,955 |

Table 8.1 Base Estimates (£) for Refurbishment of Typical Bellman Hangar

The cost estimates for doors are for their refurbishment. Replacement costs for the doors would range from £38,360 to £52,454 and removal of doors and installing vehicle access only would range from £31,625 to £45,744, dependent in all cases upon the respective heights of the hangar.

If a 3.15m high brick dado wall is built around the perimeter of the building, then an extra over cost of £17,200 will be incurred.

The costs for the new build hangar are for a "like for like" alternative to enable comparisons to be made. As stated in Chapter 7.0, in reality the Project Sponsor's requirements may vary as per current operational practice. The new hangar has been costed for construction on the same site as the existing hangar. If a green field site were chosen, the cost of site preparation and laying new services may vary, depending on site specific conditions. The new build costs include for providing a replacement ground slab at £96,600. If this were omitted and the existing ground slab used and patch repaired where necessary, then the above cost would reduce by approx £83,300 after allowing for some repairs and cutting out of the existing slab.

| Work Item | 45 m/s | | 48 m/s | | 52 m/s | |
|---|---|---|---|---|---|---|
| | 2 unit high | 3 unit high | 2 unit high | 3 unit high | 2 unit high | 3 unit high |
| Demolish and clear site | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| Foundations | 15,469 | 15,469 | 18,590 | 18,590 | 21,560 | 21,560 |
| Ground Slab | 96,600 | 96,600 | 96,600 | 96,600 | 96,600 | 96,600 |
| Steelwork | 56,861 | 64,263 | 56,861 | 64,263 | 81,416 | 88,818 |
| Purlins and Rails | 14,724 | 16,004 | 14,724 | 16,004 | 14,724 | 16,004 |
| Cladding | 105,600 | 117,360 | 105,600 | 117,360 | 105,600 | 117,360 |
| Doors | 38,360 | 52,454 | 38,360 | 52,454 | 38,360 | 52,454 |
| Flashings, etc | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 |
| Services | 50,000 | 50,000 | 50,000 | 50,000 | 50,000 | 50,000 |
| TOTAL | 393,614 | 428,149 | 396,735 | 431,271 | 424,260 | 458,796 |

Table 8.2 Base Estimates (£) for New Build Bellman Hangar

When the existing floor slab is modified and re-used and the cost of approx £83,300 is discounted from the total cost of a new build hangar, it becomes obvious that the refurbishment costs are more or less similar to the new build costs. A new build hangar will have a longer design life and can be designed to require much less maintenance than a refurbished hangar. Also a new hangar can be designed exactly to present day operational needs and thus running costs can be reduced. All such factors including any other indirect costs over the life of the two options should be taken into account in an investment appraisal.

For hangars which are heated, the use of modern insulated cladding panels would give a saving of £8,700 to £10,300 per year for heat loss dependent upon height of hangar and assuming a `U' value of 0.45 $W/m^2K$.

# PAGE LEFT INTENTIONALLY BLANK

# 9.0 STANDARDS

It is Government Policy that although the Crown is exempt from the provisions of the various Building Acts and Regulations all construction carried out on behalf of Government Departments is to comply with the substantive requirements of the relevant Acts of Parliament and Statutory Instruments, and that this compliance can be demonstrated.

## 9.1 BUILDING REGULATIONS

The application of Building Regulations is not retrospective but where major refurbishment works are carried out to the structure or cladding, these may be considered to be a "material alteration" and the refurbishment work will then be subject to the Building Regulations.

An alteration is material for the purposes of the Building Regulations if the work, or any part of it, if carried out by itself would adversely affect the existing building in relation to compliance with requirements for structure, means of escape in case of fire, internal or external fire spread, the provisions for disabled people, etc.

The requirement is in compliance with Part A of the Building Regulations 1991 for England & Wales, Part C of the Building Standards (Scotland) Regulations 1990 or Part C of the Building Regulations (Northern Ireland) 1994, and including all current amendments. The appropriate Regulations will be determined by the location of the works.

Further advice on compliance with Building Regulations is available from:

Building Control Officer
HQ DWS
P O Box 1734
Rectory Road
Sutton Coldfield
West Midlands
B75 7QB

Tel: Sutton Coldfield Mil Extn 2185
Fax: Sutton Coldfield Mil Extn 2187

## 9.2 MOD FIRE STANDARDS

MOD Fire Standards and in particular Fire Standard E10 - "Aircraft Hangars" are mandatory for all new build hangars and they are to be applied, so far as is reasonably practicable, when major refurbishment or modernisation of hangars is carried out. The MOD Fire Standards are not however retrospective and, where for example only limited renewal works items such as roof cladding are carried out, then only that element of the works is required to comply with the Standard.

It should be noted that the relevant MOD Fire Standard to be applied is determined by the proposed use of the hangar building and not by what it was built for originally. Therefore MOD Fire Standards E9 - "Garages, Vehicle Workshops, Vehicle Storage and Car Parks in Buildings" or E11 - "Storage Premises" may be the relevant Fire Standard.

Further advice on compliance with the respective Fire Standards is available from:

Senior Fire Prevention Officer
HQ DWS
P O Box 1734
Rectory Road
Sutton Coldfield
West Midlands
B75 7QB

Tel: Sutton Coldfield Extn 3634
Fax: Sutton Coldfield Extn 2187

ANNEX A

## Change Suggestion Form

| | | |
|---|---|---|
| | **Defence Works Services**<br>**Airfields and Bulk Fuels Group**<br>**P O Box 1734**<br>**Rectory Road**<br>**Sutton Coldfield**<br>**West Midlands**<br>**B75 7QB** | **Guide to World War II Hangars**<br>**01-Bellman Hangar**<br><br>**Change Suggestion Form** |
| Originator: | | Date:<br>Ref: |
| **Change Suggestion** | | |
| Section: | | Page: |
| Change Detail:<br>Continuation Sheet included ? Y ❑ N ❑ | | |
| Reason:<br>Continuation Sheet included ? Y ❑ N ❑ | | |
| **DWS Review** | | |
| Action: | | Ref:<br>Action Date:<br>Approved:<br>Actioned: |

# PAGE LEFT INTENTIONALLY BLANK

# REFERENCES

1. BS 449: Part 2: 1969: Specification for the Use of Structural Steel in Building, incorporating Amendment No 8 (AMD 6255, December 1989).

2. BSI CP3: Chapter V: Part 2: 1972 - Code of Basic data for the design of buildings Chapter V: Loading, Part 2: Wind loads ISBN 0 580 074536.

3. BS 5950: Part 1: 1990: Structural use of steelwork in building.

4. BS 6399: Part 1: 1984 Code of Practice for Dead and Imposed Loads, Part 3: 1988: Code of Practice for Imposed Roof Loads.

5. Building Research Establishment Digest 346 December 1990 ISBN 0 85125 473 X.

6. Historical Structural Steelwork Handbook Publication No 11/84, The British Constructional Steelwork Association Limited, ISBN 0 85073 015 5.

7. Health and Safety at Work etc Act (1974), HMSO.

8. DWS Specification 005 Issue No 002, June 1992: Property Management of the Defence Estate.

9. DWS Technical Bulletin 39/94: Hangars - Safety of Structure - Recommendations for Users During Adverse Weather Conditions, August 1994.

10. DWS Technical Bulletin 40/94: Hangars and Industrial Buildings - Inspection, Maintenance, Adjustment and Use of Large Sliding and Folding Doors, August 1994.

11. DWS Technical Bulletin 55/94: Hangars - Bellman Type - Safety Precautions - Recommendations for Users During Adverse Weather Conditions, December 1994.

12. Defence Works Functional Standard 06: Guide to Airfield Pavement Maintenance, HMSO ISBN 0 11 772730 X.

13. Lighting Guide No 1 "The Industrial Environment" 1989, Chartered Institute of Building Services Engineers (CIBSE).

14. Services Accommodation Code, Joint Services Publication (JSP) 315.

15. Secure Building Specification for Industrial Type Buildings, DOE Special Services Group.

16. MOD Fire Standard E10 - "Aircraft Hangars", November 1993.

17. MOD Fire Standard E9 - "Garages, Vehicle Workshops, Vehicle Storage and Car Parks in Buildings", April 1987.

18. MOD Fire Standard E11 - "Storage Premises", April 1987.

19. Building Regulations 1991 for England and Wales.

20. Building Standards (Scotland) Regulations 1990.

21. Building Regulations (Northern Ireland) 1994.

22. Building Research Establishment Report 143 : Thermal insulation : avoiding risks : A guide to good practice in building construction 1989 ISBN 0 85125 3830 (BRE).

Prepared by: Airfields & Bulk Fuels Group, DEO(W)

**DEFENCE ESTATE ORGANISATION (WORKS)**
**Ministry of Defence**
St Georges Barracks, Blakemore Drive
Sutton Coldfield, West Midlands, B75 7QB

| | | |
|---|---|---|
| **Telephone**: | (Reception) | 0121-311 2140 |
| | (ABFG) | 0121-311 3789 |
| | (Facsimile) | 0121-311 3636 |