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Impact of Antarctic Climate on Structural Components and Life Support Systems of Maitri Station

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Abstract

The Indian Antarctic Station 'Maitri', indigenously developed by R&DE (Engrs), Pune and constructed in Antarctica in the year 1988-89, needs regular monitoring of structural components and Life Support Systems. A long term scientific programme has been projected to DOD by R&DE (Engrs).

Preliminary studies have been carried out during the summer period of 13th Antarctic Expedition, for examining the impact of climatic conditions of Antarctica on the structural components of the station building and on other infrastructural facilities like water supply, heating and power generation systems.

This paper contains the details of the preliminary studies conducted at Maitri between January and February, 1994 i.e. the summer period of 13th Expedition. Based on these studies certain observations are made and recommendations have been indicated. The improvements suggested need implementation during future expeditions. Also a long term engineering studies' programme should be undertaken from the year 1995.

Introduction

Although R&DE (Engrs) has been participating in Antarctica Expeditions since 1983, most of the system designs have been based on empirical methods with a hope that they will work satisfactorily in Antarctica. Antarctic structures and systems fall in the category of cold region engineering and there is no agency in the country directly and wholly working on these aspects. It has been a common notion that the provision of the facilities at Antarctica is simply a logistic activity, implying thereby that there is no need for research and development and experimentation. Obviously, this is not true. R&DE (Engrs) could help build a technology base in cold region engineering to serve the purpose of supporting Antarctic expeditions in a more scientific manner.

The scientific studies in Antarctica, in the field of Engineering have been commenced from the 13th (1993-94) Indian Scientific Expedition to Antarctica. The Indian Antarctic station 'Maitri' indigenously developed by R&DE

(Engrs), is now 6 year old and requires constant attention for maintaining the structural components of the station building and the service systems. The preliminary studies during summer period of 13th expedition involved studies of the impact of Antarctic environmental conditions on the structural components of Maitri station building and on other infrastructural facilities like water supply, heating, power generation and sewage disposal systems provided for the station.

The structural components of foundation framework and superstructure of the station building have been thoroughly examined and effects of very low (sub-zero) temperatures and high winds of Antarctica have been studied. Also the impact of these conditions on the service systems has been examined. Samples of steel component and insulated panel lying in the open near Maitri station for the last 5 years have been brought to India for testing in laboratory.

Maitri Station

Maitri Station is located at Lat. 70°45'S; Long.l l'WE at a site in Schirmacher Range of Queen Maud Land, East Antarctica. This is a ice free mountainous terrain where the problem of permanent accumulation of drifting snow does not exist. There is a lake in the vicinity of the station. The site plan of Maitri location is at Fig. 1.

Structure

The structure of the main station has been constructed on stilts and partially on relatively level ground to cater for uneven surface. The structure has been designed to withstand low temperature and high wind speed. The substructure consists of foundation framework, made out of structural steel, having adjustable columns and beams fixed over these. The superstructure consists of insulated panels using polyurethane foam. The design of this structure consists of standard modules of 10' x 8' and a few large rooms. The station consists of four blocks. The main block houses living accommodation, medical facilities, communication control system and IMD laboratory. The block 'A' accommodates power supply system and workshop. The block 'B' accommodates central heating system, water storage tanks, snow melt plant, kitchen and dining hall. It also accommodates sanitary facilities like bathing cubicles and chemical toilets. Block 'C provides accommodation for incinerator type toilets. Adequate storage facility has been provided in the loft above the main block. The layout plan of the station building is at Fig. 2.

SCHEMATIC LAYOUT OF MAITRI. ANTARCTICA

(NOT TO SCALE)

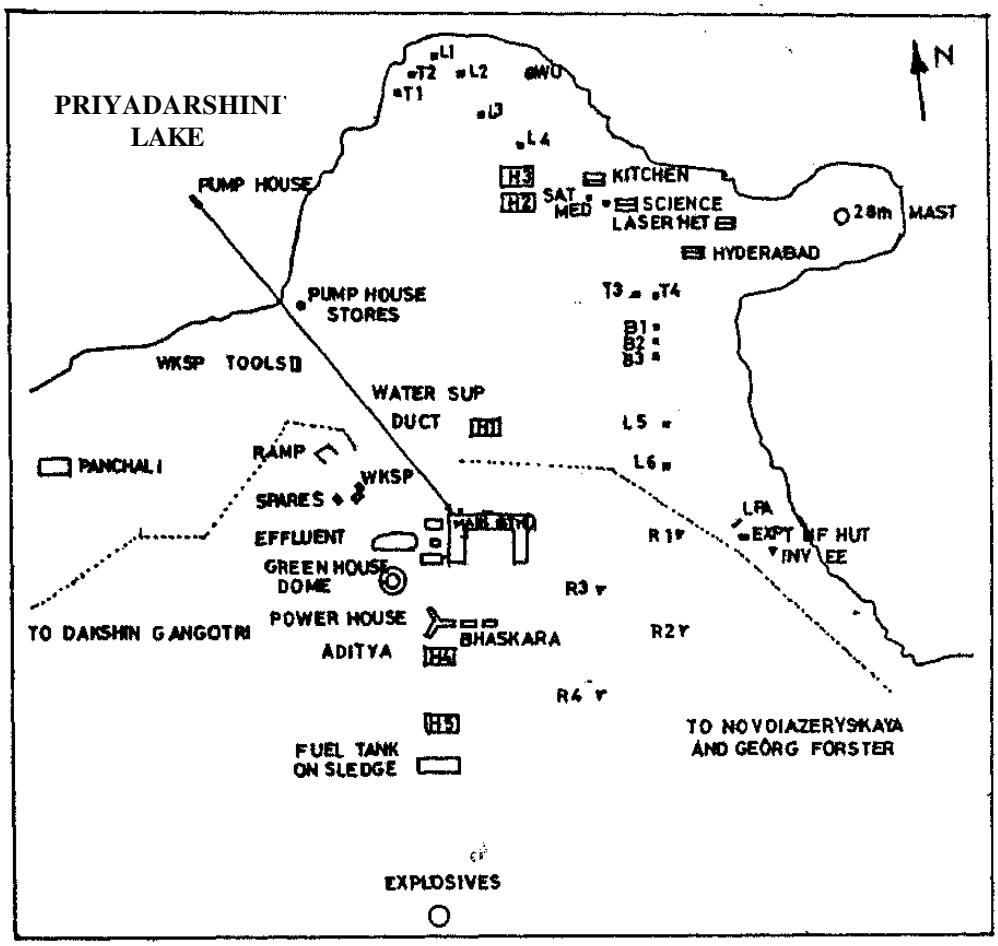
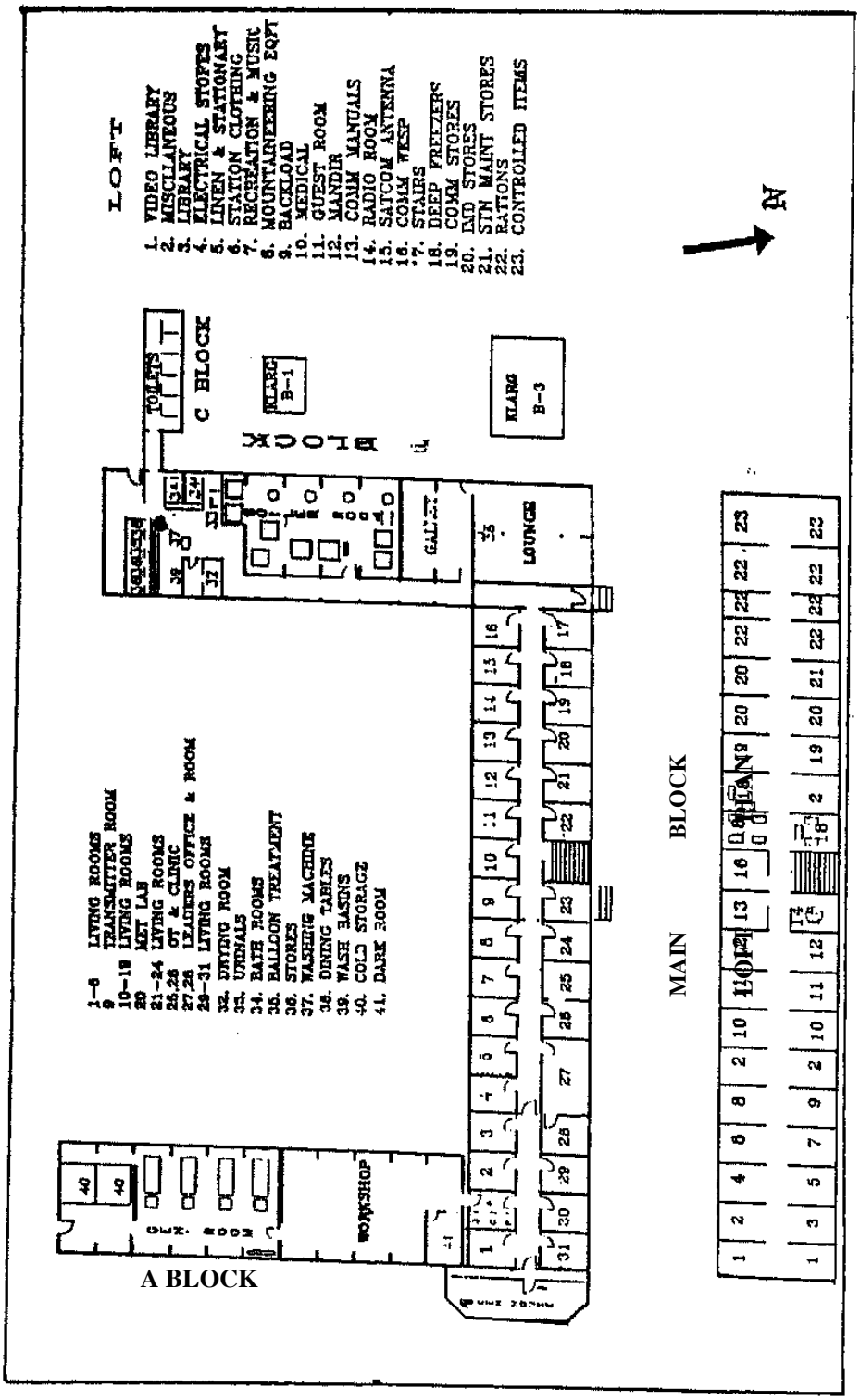


Fig. 1: T1 -T4 Toilet modules; L1-L6 Living modules; B1-B3 Bath modules; H1-H5 Helipads and R1-R4 Rombhic antenna masts

The panels of the modular construction are of marine ply, sandwiched by PU foam as insulating material and interconnected by connectors. The modules have been lined internally by a fire retardant material 'Gypsum' board and externally by 'Plastisol' coated GI sheet. The building has been well anchored into the ground. The entire station is single story except the central portion of the main block which has been raised to a double story to house the satellite communication system and on which has been placed the satellite communication dome. A cross section of the substructure and superstructure of Main Block is shown in Fig.3. /


MAITRI
LOFT
1. VIDEO LIBRARY
2. MISCLLANEOUS
3. LIBRARY
4. ELECTRICAL STORES
5. LINEN & STATIONARY
6. STATION CLOTHING
7. RECREATION & MUSIC
8. MOUNTAINEERING EQPT
9. BACKLOAD
10. MEDICAL
11. GUEST ROOM
12. MANDIR
13. COMM MANUALS
14. RADIO ROOM
15. SATCOM ANTENNA
16. COMM WKSP
17. STAIRS
18. DEEP FREEZERS
19. COMM STORES
20. LAD STORES
21. STN MAINT STORES
22. RATIONS
23. CONTROLLED ITEMS
N
C BLOCK
TOILETS
BLOCK
KLARC B-1
KLARC B-3
GALLEY
LOUNGE
1-6 LIVING ROOMS
9 TRANSMITTER ROOM
10-19 LIVING ROOMS
20 MET LAB
21-24 LIVING ROOMS
26,26 OT & CLINIC
27,28 LEADERS OFFICE & ROOM
29-31 LIVING ROOMS
32. DINING ROOM
33. URINALS
34. BATH ROOMS
35. BALLOON TREATMENT
36. STORES
37. WASHING MACHINE
38. DINING TABLES
39. WASH BASINS
40. COLD STORAGE
41. DARK ROOM
GEN. ROOM
WORKSHOP
A BLOCK
MAIN BLOCK
HOIST
HANGAR

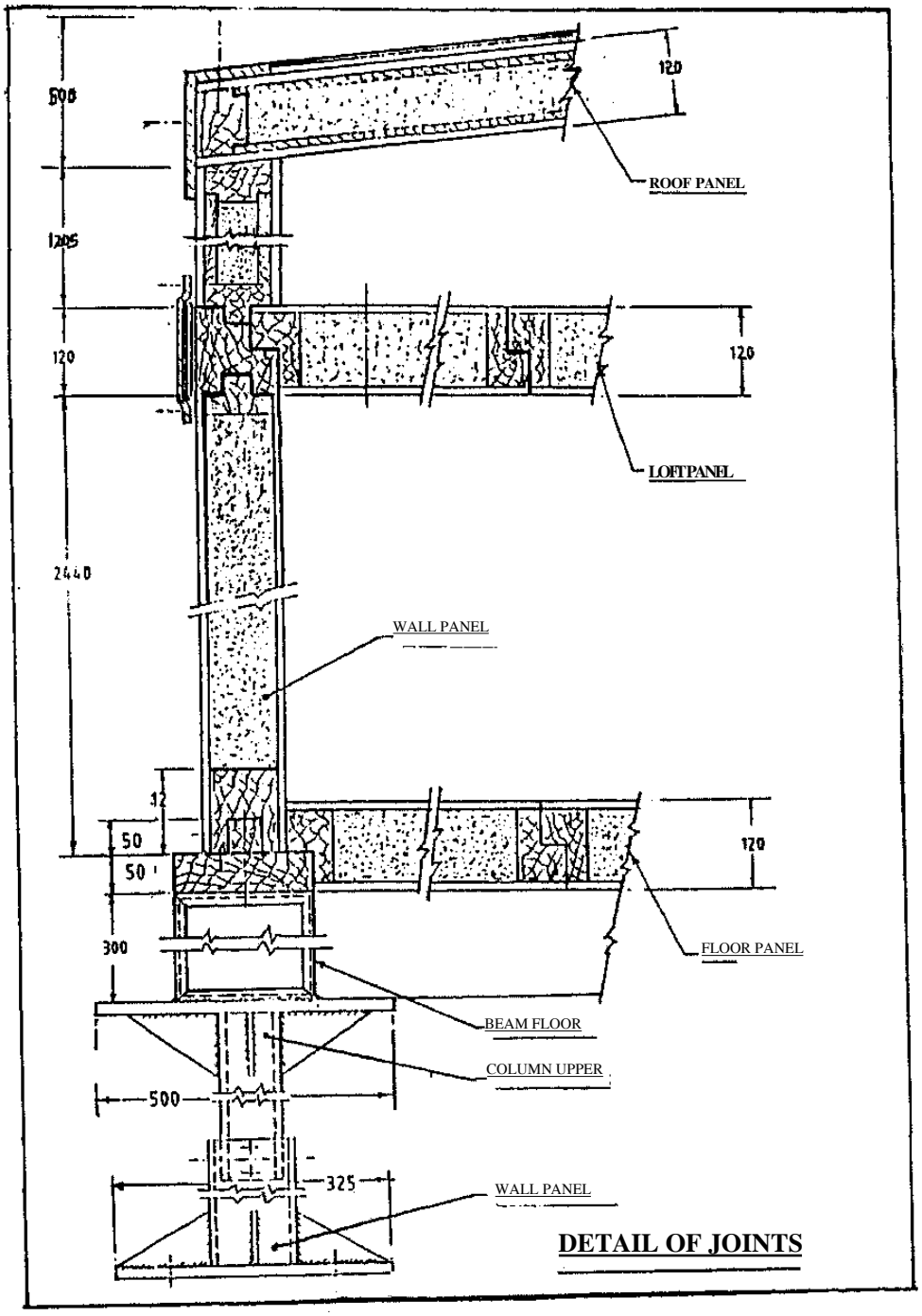

600
1205
120
2440
120
ROOF PANEL
120
LOFTPANEL
WALL PANEL
12
50
50
300
120
FLOOR PANEL
BEAM FLOOR
COLUMN UPPER
500
325
WALL PANEL
DETAIL OF JOINTS

Fig. 3

Service Systems

Power Supply System: The electric power generation system forms an essential part of the life support system at Maitri station. The power generation is provided with the use of Diesel Electric Generating sets. Maitri station, when commissioned in 1989-90, has been provided with 4 x 62.5 KVA gensets for power supply and 1 x 30 KVA genset for communication. These gensets have been proven and giving good service. Since these sets were to complete the recommended number of hours, it was planned to provide centralized main power station to be housed in separate building with a view to avoid fire risk to the main building and to avoid noise pollution to the occupants. Hence a new power house 'Aditya' has been constructed and commissioned during XII expedition. It is a small' Y' shape complex consisting of three knock down type steel containers of size 9 m x 2.7 m x 2.7m similar to ISO type containers. Four gensets sets of 62.5 KVA have been installed, two each in the two containers and the third container is provided as a control room. Each container has been provided with strengthened floor for direct mounting of gensets on the floor. Antivibration mountings have been provided for mounting of gensets and reduction of structurally borne noise.

Heating System: The station building has been centrally heated to provide comfortable living and working conditions. The central heating system consists of 64 radiators of 1000 K cals/hour capacity heated by circulating hot water and anti-freeze mixture at about 65 deg. C to 75 deg. C temperature. Four hot water generators of 2 lakh K cal/hour capacity, each connected by pipe lines to the radiators, meet the entire head load of the station. Out of these only one is used at a time, the second is switched on to meet the peak load, the third being a standby, and the fourth for maintenance. Two fuel tanks of capacity 2500 litres each are connected in parallel from which fuel is pumped to the daily tank (500 litres capacity) of the hot water generator.

Water Supply System: Water supply to the Maitri station has been catered for by pumping water from a lake approximately 255 metres away. A submersible pump has been lowered 80 metres from the edge of the lake. The pump is enclosed in two concentric stainless steel jackets which are heated electrically. This is necessary to ensure a continuous flow of water even at a low temperature of minus 40 deg. C. To further ensure a continuous flow from the pump to the boiler room in the main station, the entire copper pipe line has been enclosed in air tight insulated ducts supported on a steel structure. The water from the lake is pumped to two stainless steel tanks of 2500 litres capacity each, located in the boiler room. The storage tanks are connected to two hot water generators and further to the utility points. A control panel, suitable for operation of pumps, heating system and solenoid valves, is located in the pump house and the control

circuit is kept inside the boiler room for operation. A snow melt plant of 1000 litres capacity has also been provided in Block 'B' as a standby arrangement during the winter.

Disposal System: A separate Block 'C' has been constructed as a toilet block. Incinerator type toilets, 4 Nos have been installed in this block for regular use. Dispomatics are provided in the kitchen, dining hall, MI room and laboratory for disposal of solid wastes. The waste water from the kitchen and bath rooms is carried to the two treatment plant rooms where bio-disc treatment plants 'Klargesters' are located. The plants treat the waste water by biodegradation process and the treated water is allowed to flow to the soakage pit located nearby. The water from soak pit is pumped once or twice a year to a far off location towards glacier.

Electrical System: Each room and all corridors of the four blocks of the station building have been suitably illuminated by the electrical system. Power supply for this system is obtained from 62.5 KVA gensets. Effort has been made to select the best suited cables, switchgears, exhaust fans and luminaries for low temperature conditions. Instead of going for heavy and bulky PVC/rubber cable, PTFE (Teflon) silver plated copper wire has been used for the complete system. Light miniature breaker with built in protection against over load and short circuit have been used instead of conventional heavy iron clad switches, distribution boards and porcelain fuses. Miniature earth leakage circuit breakers have also been used to avoid fatal current of more than 30 mA through human body. Silver contact switches have been provided for longer life.

Structural Studies

Substructure: The steel components of the foundation framework of the station building have been thoroughly examined for any cracks in the structural member or the welded joints and random measurement of thicknesses have been conducted. No cracks have been found and no failure of welded joints observed. Diagonal measurement at four comers of foundation columns were taken at about twenty different locations of the foundation framework to detect settlement of steel columns, if any. It has been observed that there is no uneven settlement of columns of the foundation framework. Samples of spare steel columns of the foundation framework, lying in the open for the last 5 years near Maitri station have been brought to India and tested in our laboratory. The test results are at Annexure 'I'.

Superstructure: All the insulated panels of the superstructure have been examined and joints studied. Monitoring, of temperature in each living room of the Main block at 5 days' interval has been conducted and the ambient

temperature and wind velocities prevailing in the outside atmosphere at the time of measurement have been noted for evaluation of the insulation properties of the panels of the building structure. The readings are at Annexure 'II'.

Service Systems

All service systems, such as water supply, central heating, power supply and sewage disposal system have been thoroughly examined. Noise level measurements at various locations inside the station building and in the new power house Aditya, have been carried out. The readings are at Annexure 'III'. Samples of drinking water and treated waste water have been collected and tested for detection of faecal pollution by the field test method developed by DRDE, Gwalior. Test results are at Annexure IV.

Observations

Based on the visual examination and measurements/readings taken at Maitri station and tests conducted in laboratory, following observations are made.

Substructure: The foundation framework made out of structural steel has so far withstood the impact of very low (sub-zero) temperatures and highly windy and blizzardous climatic conditions of Antarctica. On thorough examination of various components of framework and their welded joints it has been observed that the components have not developed any cracks and there is no failure of welded joints so far. After carrying out the thickness and other dimensional measurements it is seen that the components do not show any deformation.

Two samples of spare steel columns of foundation framework lying in the open and exposed to Antarctic climate for the last 5 years, in the vicinity of Maitri station, were brought to India for testing the mechanical properties of the steel material in our laboratory. The material has been tested and the test results are at Annexure 'I'. From the test results of the steel material it is observed that so far there is minimal change in the mechanical properties of steel. The properties are within the specified limits.

Superstructure: The temperatures in all the living rooms of the station building have been monitored every 5 days and outside ambient temperature on these days have been noted. The readings are at Annexure 'II'. It is observed from these readings that the insulation properties of the panels of the superstructure appears to have no effect so far, of the impact of Antarctic climatic conditions. It has also been observed that the living rooms on the rear side of

the Main Block i.e. on the south, have been found to have lower temperatures as compared to the living rooms on the front side, particularly during winter months. Therefore, these rooms need extra heating. The humidity in living rooms is nil which makes living of humans uncomfortable, as such, small humidifier may be provided in each living room, in the future.

Apart from the study of main station the 28M mast erected near the summer camp was also examined. There is no dimensional change in the structure of the mast. However the mast needs proper maintenance.

All the panels/components of the superstructure have to be thoroughly examined and the following observations are made :

(a) Some of the roof level joints of the insulated panels of Block 'A' and Block 'B' which are facing East (the wind direction at Maitri) have been affected due to high winds and ingress of snow has been observed, during blizzards, by the wintering team. Silicon sealing compound has been used for sealing the gaps, but this has not been found very effective in the long run. As such, some other, more effective sealing compound should be sent in the next expedition for permanent sealing of such gaps at the joints.

(b) Similar conditions of ingress of snow through the joints of panels of green house have been observed, since the green house is directly facing East, which is the wind direction. Stronger sealing compound should be sent in the next expedition for sealing of all the joints of the panels of the green house.

(c) The toilet block i.e. Block 'C', needs major repairs because of ingress of snow through joints. Also layer of soot has been deposited on the inner surface of all the panels of this block since the incinerator type toilets have been housed in it, which are fired every day, causing lot of smoke. The exhuast system also needs improvements. This block should either be undertaken for major repairs or constructing anew, in the next expedition.

(d) It has been observed by the wintering team member that the floor panels do not provide adequate insulation during winter. The temperature varies from minus 4 deg C at floor level to plus 15 deg C at roof level. It is suggested that additional layer of insulation material be provided for the floor in all living rooms.

(e) The inner fireproof lining of gypsum board provided for the wall and roof panels of each living room has been found to be extremely effective. This has been proved when actual fire broke in one of the living rooms on the 5th Feb' 94, on account of the explosion of an explosive object

lying in the room. Even though all the clothing items, wooden furniture and some other items in the room were burnt completely, the wall and roof panels of the room did not catch fire. As a result the structural strength and insulation properties of the panels have not been affected. Also the fire neither spread to the adjacent rooms nor to the corridor.

Recommendations

Based on the above observations the following recommendations are made:

(a) The spare steel column of the foundation framework tested in laboratory does not show any degradation so far in the mechanical properties of the material. However, studies on the structural properties of loaded components of the foundation framework should be undertaken on a long term basis.

(b) The insulated panels of the superstructure are providing adequate insulation. However, the rear side living rooms need additional heating during winter period. Either a thin layer of additional insulation may be provided for these rooms or alternatively extra heating should be provided. Also a thin layer of additional insulation is needed for the flooring in all the rooms.

(c) For more effective sealing of joints of the insulated panels of the superstructure a new type of sealing compound having better qualities than the silicon sealing compound should be provided. A lot of gaps in the insulated panels have been observed in Block 'A', 'B' and the green house, which need sealing by means of a stronger and durable compound.

(d) Major repairs should be undertaken for the toilet Block 'C or the block may be constructed anew. Also new incinerator toilets of improved version may be provided.

(e) The noise level measurements conducted at various locations inside the station building indicate disturbance in the living rooms at night. It is suggested that the generator room in Block 'A' and boiler room in Block 'B' should be vacated in due course of time and housed in detached blocks like 'Aditya' power house.

(f) The three numbers of MS tanks of the water supply/heating system installed in the boiler room of Block 'B' need replacement because the same are largely rusted scaled from inside.

(g) The water from the Priyadarshini lake is pumped into the station and used for drinking, bathing, washing, heating etc. The sample of water

drawn from this lake at the pump house end, was tested with the help of the field test bottles provided by DRDE, Gwalior. The samples of water did not indicate any faecal pollution and found fit for drinking. However, the treated waste water at the outlet of the Klargester when tested by the same method (though not meant for this purpose), indicated faecal pollution. Samples of the waste water have also been drawn by rep. from NEERI, Dr. TK Ghosh, for physiochemical analysis in their institute, the results of which may be ascertained.

(h) The steel structure of the 28 M Mast erected near summer camp is intact so far, but it needs proper maintenance. The structural framework should be painted with epoxy based paint Also new guy ropes should be provided in place of the existing guy ropes.

Conclusion

Only preliminary structural studies could be carried out during the short summer period of 13th Antarctic expedition. Based on these studies, certain recommendations have been made for improvement of the life of the structure and improvement of living conditions at Maitri station. Suggested improvements should be implemented during future expeditions. It is also necessary that a long term engineering studies programme for monitoring structural components of the station building and the Life Support Systems should be undertaken during wintering period for the next 3 to 5 years, as suggested in the scientific studies programme projected to DOD by R&DE (Engrs).

Acknowledgements

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Annexure I: Test Results of Steel Column

Test Specimen No.	U.T.S. (Kg/mm^2)	% Elongation at Break
1	41.730	40.00
2	40.904	35.00
3	40.902	32.20
4	40.878	32.20

Annexure II: Monitoring of Temperatures in Living Rooms of Maitri Station

Date	15 Jan 94	20 Jan	25 Jan	30 Jan	04 Feb	10 Feb	.20 Feb
Time	0830 Hrs	0830 Hrs	0930 Hrs	0930 Hrs	0930 Hrs	0930 Hrs	0930 Hrs
Ambient Temp.	0.0°C	2.0°C	4.6°C	-0.8°C	2.0°C	-5.5°C	-5.0°C
Wind Velocity	9Kmph	35 Kmph	17 Kmph	31 Kmph	39 Kmph	0Kmph	28 Kmph
Room no.	Temp°C	Temp°C	Temp°C	Temp°C	Temp°C	Temp°C	Temp°C
Rl	21.5	15.5	24.2	21.1	18.1	18.6	19.2
R2	14.7	8.6	17.4	16.5	16.2	17.3	18.9
R3	-	17.6	-	20.3	18.9	17.5	18.6
R4	19.5	17.5	23.6	22.2	19.9	18.2	18.4
R5	20.0	17.5	23.8	22.6	20.0	17.8	17.2
R6	21.5	16.2	24.5	23.2	20.1	18.3	16.9
R7	locked	locked	19.1	locked	19.2	18.9	17.8
R8	14.3	14.2	24.6	22.8	18.9	19.1	17.9
R9	20.8	7.5	19.5	15.9	16.1	19.5	17.0
R10	13.5	15.8	23.8	18.9	19.0	19.9	18.2
R 11	20.2	16.1	25.5	20.0	18.6	20.3	18.0
R12	20.3	16.4	26.4	21.4	18.5	20.2	18.0
R13	21.0	16.7	-	-	-	20.1	17.5
R14	21.5	17.1	27.4	21.4	-	19.9	-
R15	21.7	14.3	25.3	21.0	-	19.6	17.5
R16	21.5	14.6	24.8	20.3	18.2	19.8	18.1
F17	18.8	16.3	25.8	23.5	-	18.6	18.4
F18	21.4	16.3	26.5	-	19.2	18.4	18.3
F19	21.9	16.5	-	locked	19.3	18.8	17.6
F20	22.8	16.7	28.2	23.8	21.0	18.6	17.3
F21	22.0	16.6	26.5	21.9	18.9	17.8	19.5
F22	-	16.9	24.4	22.4	23.6	20.0	locked
F23	-	-	-	-	-	-	.
F24	21.4	18.1	24.1	-	21.9	20.3	19.7
F25	21.2	-	23.0	locked	20.0	20.2	19.4
F26	21.2	-	23.0	locked	20.0	20.2	19.4
F27	22.2	19.0	24.1	22.0	21.0	19.5	20.3
F28	22.0	18.8	23.9	22.2	21.3	19.2	21.0
F29	25.2	21.6	27.1	25.4	21.9	19.4	21.2
F30	24.1	17.2	24.8	24.9	20.8	19.5	21.0
F31	23.2	16.2	24.5	23.6	-	-	20.5
F38	-	-	23.9	23.4	19.8	19.7	19.2
Loft	-	20.7	-	19.1	19.6	21.1	18.0

Annexure III: Noise Level Measurements

Noise level (dB) (measured by NEERFs Instrument)

Permissible limits : Day time upto 55 dB
Night time upto 45 dB

17 Jan 94 - day time

(a) Actual values taken at Maitri Station

Living rooms	**35 to 40 dB**
Lounge	**44 dB**
Boiler Room	**74 dB**
Gensets Room	**98 to 98.5 dB**
Workshop	**68 to 69 dB**
Communication Room	**53 to 54 dB**

(b) Values taken at Aditya Power house (100 m away from main station) at the back

Gensets Room	**100 dB**
Operators working room	**66 to 67 dB**
Working area between Aditya & station building	**60 to 62 dB**

Annexure IV: Water Sampling; Field Test Results

Date: Description

14 Jan 94: Lake water near pump house dt. 14 Jan 94 (1000 hrs) Surface & Bed samples drawn. Waste water at inlet and outlet of Klargester Bl (not functioning) samples drawn.

15 Jan 94: Results:

Lake water - Unpolluted.

Inlet waste water - polluted (turned black after 48 hours)

Outlet waste water - polluted (turn black within 24 hours)

Repeat sample drawn at outlet point of waste water.

16 Jan 94: Result of repeated sample - positive i.e. outlet water waste is polluted (turned black within 24 hours). Station Commander was requested to put Klargester on.

24 Jan 94: Waste water samples drawn at inlet and outlet point of Klargester B1 which was functioning (only kitchen water has been connected to Bl Klargester).

Results: Inlet water - unpolluted (did not turn black). Outlet water polluted (turned completely black after 48 hours)

26 Jan 94: Waste water samples drawn at inlet and outlet of B3 Klargester, Bathrooms, urinals & washing machine water connected to it.

Results: Inlet water - polluted (turned slightly black after 24 hours & completely black after 48 hrs). Outlet water - polluted (turned slightly black after 24 hours and completely black after 48 hours).

11 Feb 94: Waste water samples drawn at the outlet of Bl & B3 Klargester.

Results: (a) Outlet composite sample B1 polluted (turned black in 24 hours) (b) Outlet composite sample B3 - Polluted (turned black in 24 hours)

26 Feb 94: Waste water samples at the outlets of Bl & B3 Klargester.

Results: Both the samples showed pollution, turning black after 24 hours.

All water samples from lake, drawn every 10 days (approx) showed unpolluted water (14 Jan, 24 Jan, 04 Feb, 15 Feb & 23 Feb 94).