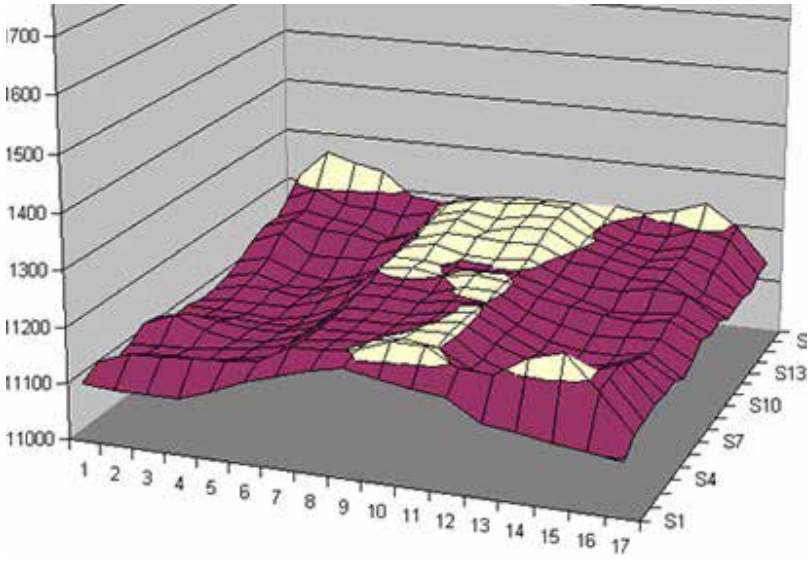
FJB Food & Temperature Controlled Consultant Engineers

CASE STUDY FROSTHEAVE

Frostheave can continue for years as the sub-soil ice increases in volume and goes deeper. In some instances floor levels have been raised by feet, not inches.



CASE STUDY FROSTHEAVE

JB Systems are specialists in the total design and project management of food processing plants and in particular chill and cold stores.

One part of FJB Systems' client base involves the detailed total assessment of existing cold and chill stores, either on the basis of 'due diligence' pending a prospective purchase, or alternatively directly for the store's owners who need advice on technical problems. Such work can involve a complete site assessment taking into account all the civil works, refrigeration systems, electrical services, insulation panel works and structural frames, so as to provide a complete report or condition survey on the existing site. Alternatively, FJB Systems are brought in to assess and make recommendations on particular site problems, such as the failure/poor condition of insulation panels, refrigeration problems/inadequacies or structural problems. One problem that FJB Systems have much experience with and have been asked to assist on many occasions, is frostheave. This brief paper describes the cause of frostheave, its symptoms and possible cures. It focuses on one particular case study where FJB Systems were brought in to assess the cause of and determine a solution for frostheave.

"..the insurers recommended that the entire floor slab be dug up and relaid.... this course of action had understandably been found by the owner of the store to be unsatisfactory, as it would mean ...his source of revenue would be taken out of action for many months."

The Cold Store Floor

Frostheave occurs when the ground under a cold store freezes and expands causing faults in the cold store floor such as cracks or slopes. Therefore cold stores which are required to operate consistently at a temperature below zero degrees celsius require specialist floor construction. This involves, amongst other things, specialist insulation, vapour sealing and underfloor heating.

To overcome frostheave, a cold store floor is typically constructed in the following manner (see figure 1); the sub-soil is compacted followed by a suitable consolidated hardcore and blinding on which a reinforced concrete sub-floor is laid. When cured, an electrical heating mat or alternatively a piping system is clipped onto this concrete sub-floor and then covered with 50mm of sand/cement screed. This screed is then covered with a heavy gauge visqueen sheet with overlapped taped joints to form a positive vapour barrier. On top of this vapour barrier, two to three layers of heavy duty insulation slabs are laid to provide the floor insulation (in the past 30 years it has been normal in the UK to utilise 150mm total thickness of high density styrofoam as the insulant and with some older stores, there is the possibility of high-density cork being used). The final phase of construction is the laying of the final concrete working floor slab, which should be designed to safely withstand the equipment required for the room operation, such as racking and reach trucks.

In this way, the cold store floor is insulated by means of thick layers of floor insulation, and the purpose of the underfloor heating system is to replace the relatively small amount of heat being removed through the insulated floor into the cold store room. Heat will always flow from warm to cold. It is usual for the sub-floor temperature to be maintained at about +4degC by the heating system. Usually this temperature is monitored by a number of independent temperature probes. Without this process of adding heat, the underfloor temperature would fall and the ground will ultimately freeze. The resultant ice expansion creates substantial forces which will push the floor slab upwards (hence frostheave). This upward motion can continue for years as the sub-soil ice increases in volume and goes deeper. In some instances floor levels have been raised by feet, not inches.

CASE STUDY FROSTHEAVE

Symptoms and Problems of Frostheave Frostheave is a slow occurring development. Each site and frostheave case has different circumstances and reacts differently – rarely are two cases identical. Ambient temperature, size of the store, soil conditions and water table all contribute to the speed of the frostheave and its severity.

The first signs of frostheave can take several forms, prior to the heave becoming so severe that it is obvious:

- Cracking of the working slab (see figure 2).
- Apparent (although not actual) subsidence of the perimeter walls of a store.
- Gradients within the store caused by the heave.
- Inability of mobile racking to move/premature wearing out of motors.
- Rising of internal support columns (if present).

In its extreme, frostheave can cause the following problems:

- Eventual complete displacement of the building's foundations when the ice finally reaches the bottom of the column foundations.
- Excessive cracking of the floor, resulting in the rapid degradation over time of the working floor surface.
- Inability of forklifts to 'climb' the gradients imposed on the floor, particularly when ice forms on the floor surfaces.
- Slipping of personnel and resultant injuries.
- Inability of forklifts to accurately place pallets in higher racking, due to the angle of the floor.
- Inability of the racking to safely stand up.

The Case Study

FJB Systems were called in to view a cold store, which it was thought had been affected by frostheave and to make suitable recommendations. In this instance, the building's insurers had previously sent surveyors who had recommended that the entire floor slab be dug up and the heater mat, insulation and working slab be completely re-laid. This course of action had understandably been found by the owner of the store to be unsatisfactory, as it would mean that the store and therefore his source of revenue would be taken out of action for many months.

The store measured approximately 40 (L) x 30 (W) x 8 (H) metres and had operated continuously at –25degC for three years prior to any problem being perceived. The store was fully installed with mobile racking and the first sign of a problem that the management noticed was that the motors on the mobile racks were burning out prematurely. Later, cracking was seen on the floor surface and only later still did the rise in floor level become obvious. At this point the company's insurers were called in and later FJB Systems. The largest rise of the floor at the worst point of the heave was then found to be120mm (see figure 3).

In this case, two heater mats had been laid, each covering half of the store, each heater mat had its own independent controller, which was operated by a temperature probe located under that mat. Electrical testing and inspection of the system identified that the fundamental problem was with the installation.

"FJB Systems not only directly saved this client hundreds of thousands of pounds with the simplicity of their solution but also cut possible future costs "

All of the underfloor temperature probes had been incorrectly installed. The probes had been pushed through a plastic conduit that laid along side the heater mat, however the probes that were meant to lie under the second heater mat had not been pushed through far enough and were incorrectly located under the first mat and one was in fact located directly under the perimeter of the cold store.

Unfortunately, this latter probe was the specific probe designated for controlling the heater mat and as it was now under the warm perimeter of the store, the probe did not call for the second heater mat to be turned on. There were three probes in all for the second mat but all these signified high and satisfactory temperatures on their display console because they were all measuring the wrong temperature. The result of this was that the second heater mat had never actually operated since its installation and a time span of three years had been sufficient for the ice build up to push up the floor.

The Solution

In this instance, once the cause of the heave had been identified, FJB Systems sought the most simple, ecomonical and effective solution for the problem. Their recommendation was to re-wire the second heater mat control system to be permanently on. The permanent heat would, over time, melt the sub-soil ice build up.

In fact, this procedure, which FJB Systems had used on previous sites around the world, worked very well, and over time the frostheave relieved. Over a period of some 18 months the floor returned to its original level and the store was in continuous use throughout this time (this can be seen on the animation on the FJB Systems Web Site). FJB Systems also recommended that detailed and regular floor levels were taken to closely monitor the extent of the heave.

This close monitoring enabled FJB Systems to determine how close the floor was to becoming level again and therefore towards the latter part of this project, the heater mat was reduced in power to ensure that the floor did not return to a position lower than it previously was. This phenomenon can result in problems just as severe as frostheave. Ultimately, the heater mat was re-connected to the probes for the first mat, so that the two mats worked together as a single unit. Furthermore, modifications were undertaken to the heater control system so that management could easily monitor that they were continuing to function correctly.

The Conclusion

FJB Systems was able to help this client two fold, by not only providing a solution that was simple and economical, but also by installing safegaurds to ensure that frostheave would not occur again. FJB Systems not only directly saved this client hundreds of thousands of pounds with the simplicity of their solution but also cut possible future costs on unnessecary wear and tear of machinery, lost revenue or employee liability claims.

The above case is only one example of many throughout the world. What is certain is that each case will be different from the last. Finding the best solution is very much an art and not a science, and experience is often the best judge. However, two particular details are common to almost all cases of frostheave:

- Poor/incorrect heater mat installation.
- Poor control systems and safeguards.

"no heater mat control systems in the UK come with suitable safeguards. The few manufacturers that there are, are competing against one another on cost rather than quality, and they know that the insulation contractors will inevitably go with the cheapest supplier. "

FJB Systems believe that the first item can only be resolved by having separate independent monitoring of the heater mat installation including testing of the heater mat continuity prior to and after installation, as well as ensuring correct temperature probe location. Regardless of whatever contractor's guarantees or warranties are offered, these guarantees are worthless when you are in the situation where your floor has to be dug up and your business is set to lose its main source of revenue. The small cost of employing in a qualified professional to oversee this part of a project is negligible. Also, FJB Systems always insists that the heater mat is only installed by its manufacturer, and no one else.

One could argue that once properly installed, and proven to be so, it is not necessary to have a wealth of safeguards on the heater mat control system. Unfortunately, although this will be correct in the majority of installations, there will inevitably be one system that does fail over time, even if correctly installed. The heater mats must therefore incorporate sufficient information on their control systems to inform the management if something is incorrect or has failed. Unfortunately, as the years have progressed, the emphasis for the heater mat manufacturer has been on providing cheaper and cheaper units, as opposed to improving quality. FJB Systems believe that there are no heater mat control systems in the UK that come with suitable safeguards. The few manufacturers that there are, are competing against one another on cost rather than quality, and they know that the insulation contractors will inevitably go with the cheapest supplier.

To overcome these problems, FJB Systems offers 'the whole solution' from specifying the exact control systems necessary for the heating mats, and ensuring that these be custom made and monitoring their correct installation. Thus providing suitable safeguards. This should only add a fraction to the total cost of the installation but could save significant money in the long term. FJB Systems is not a contractor nor does it have any financial links or ties with any equipment supplier. Because of this FJB Systems provides complete independent and objective advice on which we pride ourselves.