COMPUTER SIMULATION TO AVOID PONDED ROOFS

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Computer graphing and mapping techniques have been highly developed and are being used extensively in most engineering disciplines. This paper makes use of such graphing techniques to develop computer models which pictorially simulate roof deflections under various loading conditions.

Utilizing such methods, critical areas of ponding can be avoided by allowing designers to determine with more accuracy the required size and locations of roof drains.

In the paper, actual roof areas are analyzed and graphed indicating the extent and depth of possible ponding unless adequate slope and drains are provided. To aid the reader in better understanding the use of the computer in modeling the effects of ponding, several graphs showing the deflected roofs are included.

KEYWORDS

Computer simulation, deflected roofs, drain locations, graphing, ponding, roof analysis.

INTRODUCTION

Small, personal computers are available today to virtually every type of consulting and business office. These computers perform an enormous range of tasks from word processing, to bookkeeping, to engineering calculation and computer-aided design, just to mention a few. What could only be done a few years ago on a larger mainframe-type computer can easily be accomplished today through use of relatively small and inexpensive personal computers.

Computer-aided design techniques have been complemented by the development of relatively inexpensive software. Such software is currently having a major impact on engineering design practices and procedures. Entire buildings can be designed, detailed and drawn by the use of such programs.

Some of the techniques used in computer-aided design (CAD), can be effectively used to analyze ponding and drainage effects in roofs.

ROOF SIMULATION

Before beginning the development of a computer analysis of an entire roof deck, a preliminary examination should be made to determine and take advantage of any symmetries that exist in the roof system. While most small roofs may have a relatively uniform structural framing, large roofs will normally be found to have two or more repetitive framing plans. This frequently occurs because a larger structure is usually asked to accommodate various functions requiring special rooms such as auditoriums, meeting places, standard office layouts, warehousing, etc. In addition, the use of long, deep structural members, which can include both plate girders and deep trusses, can dramatically change ponding characteristics of roofs. Other structural design considerations such as continuous structural members over a number of interior columns will also affect the deflection and runoff characteristics of the roofs.

First, all loads, both dead and live, that are expected to occur must be considered. Also, the layout of all structural members and their physical properties must be known. In addition, the initial elevation at the end of each structural member must be known.

Secondly, a gridwork or horizontal pattern is selected. The gridwork should coincide with, and along the axis of, the structural supporting members. Each grid location is then given a global location which will be utilized later in the graphic presentations. After a portion of the deck has been selected for investigation, the deflections resulting from the applied roof loads are then computed along the structural members at the grid locations. The computational procedure can be simplified by using one of the many available software programs. For the work presented in this paper, the authors chose to develop their own computer programs for determining the deflections.

The vertical deflection at each grid point is then put in a spreadsheet file such as Lotus 123 or Quattro Pro. In many cases, the worksheet may be saved as an ASCII file to reduce computing time. The resulting spreadsheet file becomes the global input file for the graphing and contour mapping software programs.

THREE-DIMENSIONAL PLOTS

From known dead load conditions together with the appropriate live loading prescribed by code, deflections of the roof structure can be predicted along any convenient pattern or gridwork. Once the roof deflections have been computed, it is a relatively simple matter to develop a global system of coordinates which will include all of the deflections previously computed. The computed deflections represent the actual displacements at various locations the roof must undergo during its life history. These relative displacements are measured from a reference plane which is established by noting the direction and slope of the roof surface without live loads. It is important during this computational procedure to separate the dead load and live load components, and to treat them accordingly.

There are a large number of software programs that will transform the global coordinates and the relative displacements into a three-dimensional graph. An example of such a graph is shown in Figure 1. By simply changing the angle of viewing by a few simple keystrokes, the computer will internally rotate the deflected structure to any desired angle. In addition, the computer can also easily change the horizontal and vertical scales to minimize or exaggerate the amount the shape deflects. The ability to view the deflected roof from various angles should greatly simplify decisions such as where to put roof drains and overflow drains or scuppers.

An obvious advantage the computer has is that a large number of "what if" scenarios can be examined by using different loading conditions. It will also assist the architect/structural engineer in identifying key structural members by noting the effect of vertical displacements on the overall roof deflections.

CONTOUR ANALYSIS

Once the properties of the structural members together with the appropriate selection of dead and live loadings have been combined to produce deflections, the use of contour mapping can be of great value. Computer mapping techniques allow the development of level curves (called contours in topographical maps). Such contours can be effectively used to determine the deflections and will determine, by inspection, the best locations for the roof drains to be installed. Figure 2 shows an example of such a contour map. It should be noted that if there is adequate slope and adequate drains there should be no ponding with the possible exception of melting snow.

By showing the actual deflections, the structural designer will be in a much better position to evaluate the structural performance of a deck. The contour mapping will also provide the roofing designer with a more thorough understanding of the roof's behavior and identify problem ponding areas so they can be designed properly.

Contour analysis can also be useful in evaluating the effect of a blocked drain and assist designers in locating overflow drains and scuppers.

EXAMPLES

The authors have selected different roof areas from a large structure which had been investigated for ponding. These areas are designated as A, B and C.

Area A had a typical beam and bar joist purlin framing pattern with column spacings of 30 feet in each direction. In addition, underlying the roof membrane was a sloping lightweight concrete fill to provide drainage. Figures 1 and 2 show a three-dimensional plot as well as a contour map of the final deflected roof under full live and dead loading of a typical two bay area without roof drains.

Area B was comprised of two long plate girders which were required due to the need for space below, uncluttered by columns. Figures 3 and 4 show the three-dimensional plot and a contour map both under full live and dead loads.

Area C posed a more complex roof framing situation in which adjacent bays produced water runoff which caused some unexpected drainage problems. Figures 5 and 6, as before, show a three-dimensional plot and a contour map of the final deflected roof under full live and dead loads for a nine bay area.

CONCLUSION

The authors believe the computer simulation of roofs is a useful method of designing roof drain systems. Once the contour maps have been drawn and related to the three-dimensional plots, the placement of roof drains becomes quite apparent. In addition, the amount of runoff at any particular drain can also be determined, thereby providing a basis for the timely removal of the water.

In this paper, the authors decided not to include the actual depths of the ponding since it would not add to the presentation of the method, but would only provide clutter. It should be mentioned, however, that in performing the work leading to this paper, the predicted actual values of deflections compared remarkably well to the deflections observed in the field.

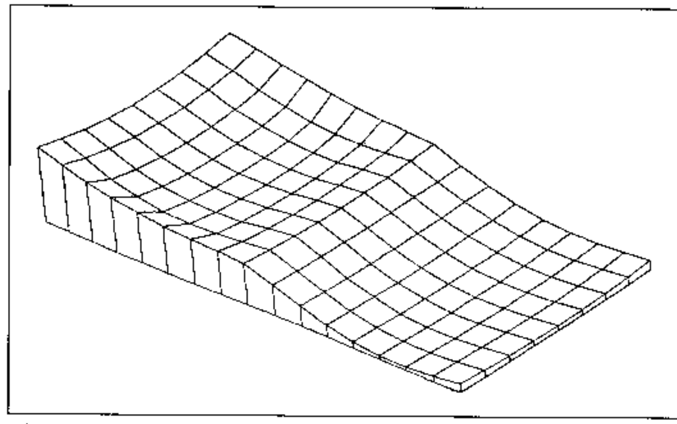

Figure 1 *Perspective view of deflected roof Area A.*

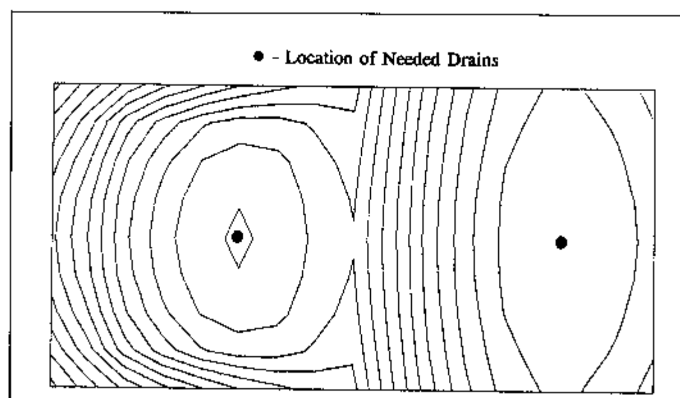

Figure 2 *Contour map of deflected roof Area A (location of needed drains).*

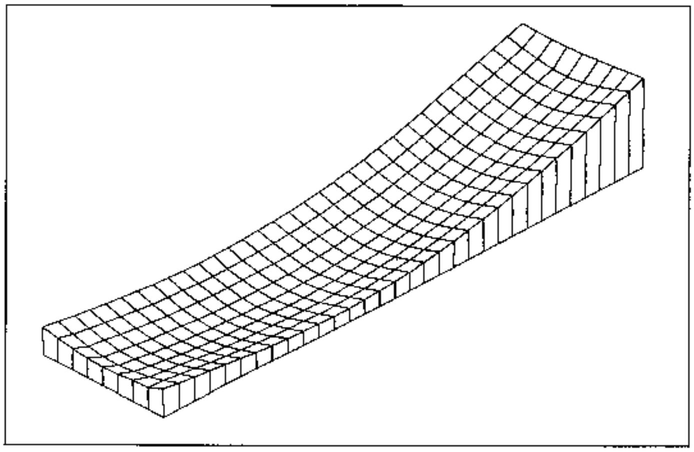

Figure 3 Perspective view of deflected roof Area B.

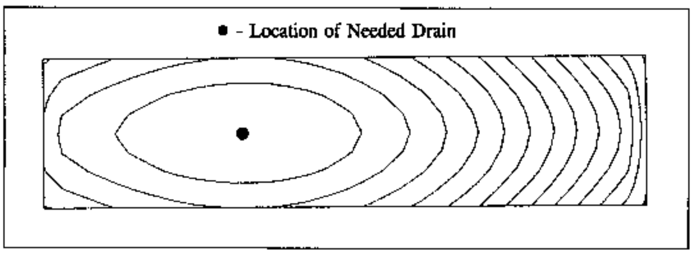

Figure 4 Contour map of deflected roof Area B (location of needed drain).

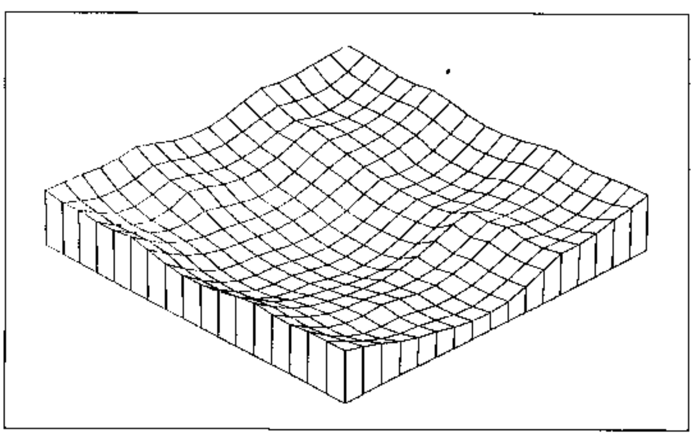

Figure 5 Perspective view of deflected roof Area C.

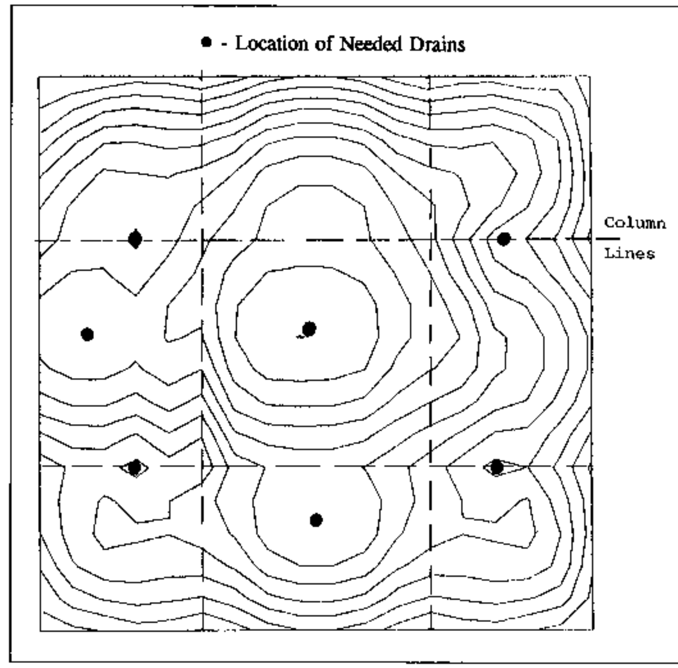

Figure 6 Contour map of deflected roof Area C (location of needed drain).