TREATMENT OF BEAMS IN FLOOR PRO

First draft

FLOOR-Pro program is capable of simulating the treatment of the structural components that are modeled as "beams" as closely as practical to "engineer's" approach. This Technical Note describes the details.

ANALYSIS OF STRUCTURE

At analysis stage, when the program generates the stiffness matrix of the structure and computes for deflections, the geometry of a beam is considered in its entirety, regardless of the location and orientation of the beam. The program correctly allows for the elevation of a beam above, below, or beams that are partially above and below a slab. The following exception applies.

❖ If user assigns "disregard" to a beam in the beam's property box, the beam will be displayed on the main screen of the program when viewing the model, but its stiffness will not be included in the analysis. Beams that are disregarded will not be displayed in the 3D results viewer.

GRAPHICAL SECTIONS

When using the tool "Create a cut at specific location ," from the toolbar below, the program creates a correct and complete image of the cross-section identified by a manually generated section cut, regardless of how a beam is defined and the treatment a user assigns to the beam. The sectional geometry of beams that are assigned "disregard" will also be displayed when using this tool.

FIGURE 1

MANUALLY GENERATED DESIGN SECTIONS

Manually generated design sections initiated from the FEM pull down menu, using the "Create Design Section Manually" menu item, are intended for design and code check. These sections are generated and treated differently from the above. The program does the following.

❖ The program disregards the presence of the structural components that are assigned "disregard" in their property window.

❖ The program determines the true cross-sectional geometry of the manual cut on a vertical plane through the depth of the floor system defined by the length of the line of manual cut on plan.

❖ The program identifies all the actions (moment, shear, etc) that pass through this section.

❖ The program identifies the details of the entire available reinforcement (non-prestressed and prestressed) that pass through the section. This includes the location and orientation of the reinforcement, as well as the force in each tendon, if any.

❖ The program idealizes the geometry of the cross-sectional into an I-shape, if the geometry of the cross section is fragmented and is more complex than the parameters of an I-section.

❖ The program calculates the sectional properties of the idealized cross-section. This consists of: area, location of centroid, second moment of area, and the section modulii of the top and bottom fibers.

❖ Using a three dimensional vectorial transformation, the program brings the entire actions associated with the cut section to the calculated centroid of the section and reduces them to six resultant components. The components are three forces and three moments. Regardless of any idealization of a complex design section, the six force components reported are always correct. The point of action of the forces on the cross section of the design section may involve an approximation for complex cross sectional geometries. This step is followed for each of the load combinations included in the program input data.

❖ For load combinations that (i) are associated with "serviceability" check, and for which the cut section includes prestressing tendons, the program calculates and reports the stresses at the extreme fibers and centroid of the section. The program does not code-check the stresses it calculates for manually generated design sections.

❖ For load combinations that are associated with "strength" check, the program (i) forms a "demand moment" using the load combination factors, (ii) determines the capacity of the section based on the base reinforcement and prestressing passing through the section, and (iii) adds and reports reinforcement that may be necessary in addition to the base reinforcement.

❖ Finally, for each design section the program reports the envelope of the reinforcement required for all the load combinations over the amount defined by user as base reinforcement.

❖ Along with the envelope of reinforcement, the program reports the positive and negative moment capacities of the section based on the base reinforcement, prestressing that may be available in the section and the envelope of the added reinforcement calculated by the program for that section.

AUTOMATICALLY GENERATED DESIGN SECTIONS FOR CODE CHECK
The prerequisite to the generation of automatic design sections and code check by the program is the presence of the following:

❖ Support Line
❖ Design Strip
❖ Supports

Support Lines define the lines that join the rows of support points along the length of a Design Strip.

Since several of the requirements of the code specifically apply to "span" , and "support" regions of a floor system, it becomes mandatory for any automated code check to associate certain regions of the domain being checked with "support" and others with "span" or field. For this reason, definition of "supports," and thereby spans are central for a complete code check. The program can detect the natural supports of design strips, such as columns, walls, and beams along a support lines.

The program is coded to operate in two modes, namely "Regular" and "Waffle/Joist" mode. It is reiterated that this distinction applies to code check of design strips. In all other scenarios, there is no such distinction.

In its Waffle/Joist mode the program is coded to properly code check and provide reinforcement for floor slab geometries that are featured in the following figure.

FIGURE 2 POST-TENSIONED WAFFLE SLAB

Program Operation in "Waffle/Joint" Mode
When in waffle/joist mode, the program considers the presence and contribution of all waffle stems that are intercepted by a design section. The intercepted stems each contribute to the cross-sectional area and other properties of the cross-section. In effect, the program generates a multi-stem design section. The reinforcement determined by the program is distributed among the waffle stems that contribute to a design section.

Program Operation in "Normal Mode"
In its normal mode the program differentiates between "architectural" and "structural" beams. The intent of this differentiation is to disregard the beams that are present in a floor system, but are not intended by the design engineer to be part of the load path in resisting the loads on a design strip. These beams will not be included in the code check. No "designed" reinforcement

will be reported for the architectural beams. The reinforcement in the architectural beams will be limited to the base reinforcement that users can define as part of input data.

The distinction between a structural and architectural beam is based on the following criteria:

❖ Architectural Beams
  o If a beam does not cross a support line, it is defined as architectural
  o If a beam crosses a support line, it can be either structural or architectural, based on the tests for structural beams that are described in the following.

❖ Structural Beams
  Beams that (i) cross a support line, and (ii) contain at least one vertex (support) of a support line within their plan outline, can be structural based on the following tests (refer to Figs 3). The smaller angle between a support line and the axis of a beam determines the classification of that beam for design purposes.

  • For α <= "angle for beam" [30 degrees] the beam is considered as "structural." The program determines the actions (moments, shear, etc) along its length, designs and code checks the beam and reports the necessary reinforcement.

  • For α >= "angle for support" [70 degrees] the program considers the beam as a "support" to the "Design Strip" under consideration. The design of these beams will be deferred to the support line in the orthogonal direction

  • For the remainder of the angles, the beam is considered as "architectural."

The parameters "angle_for_beam" and "angle_for_support" are included in the initialization file of the program and can be modified by users.
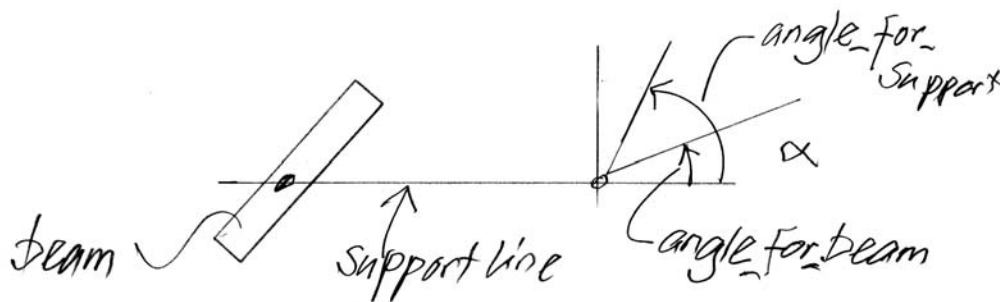

FIGURE 3   BEAM ORIENTATION WITH RESPECT TO SUPPORT LINE

Example

The partial plan of a floor system with four beams A, B, C and D, along with a support line that passes through all of them are shown in Fig. 4. The support line has two vertices (supports), one on the outline of beam A and the next on the outline of beam D.

The support line shown has a vertex within the boundary of beam A and another on beam D. In relation to the support line shown, only beams A and D are structural. The other two beams B and C are architectural, since they do not contain a vertex of the support line.

Assume the angle α between wall A and the support line be 75° and that between D and the support line 15°. Wall D will be identified as a "support" for the design strip and wall D a "beam" along its length.

The cross-sectional geometry of the design sections associated with this classification is shown in part (ii) of the figure. Note that no design section is generated between points 1 and 2 that define the stretch associated with the beam classified as support. In the creation of automatic design sections between points 2 and 3, the stems of beams B and C do not contribute. The cross-sectional geometry generated is a simple rectangle that represents the contribution of the slab only. Between points 3 and 4, the presence of beam D will result in the geometry of the cross-section generated to be in form of a T as illustrated in the figure.
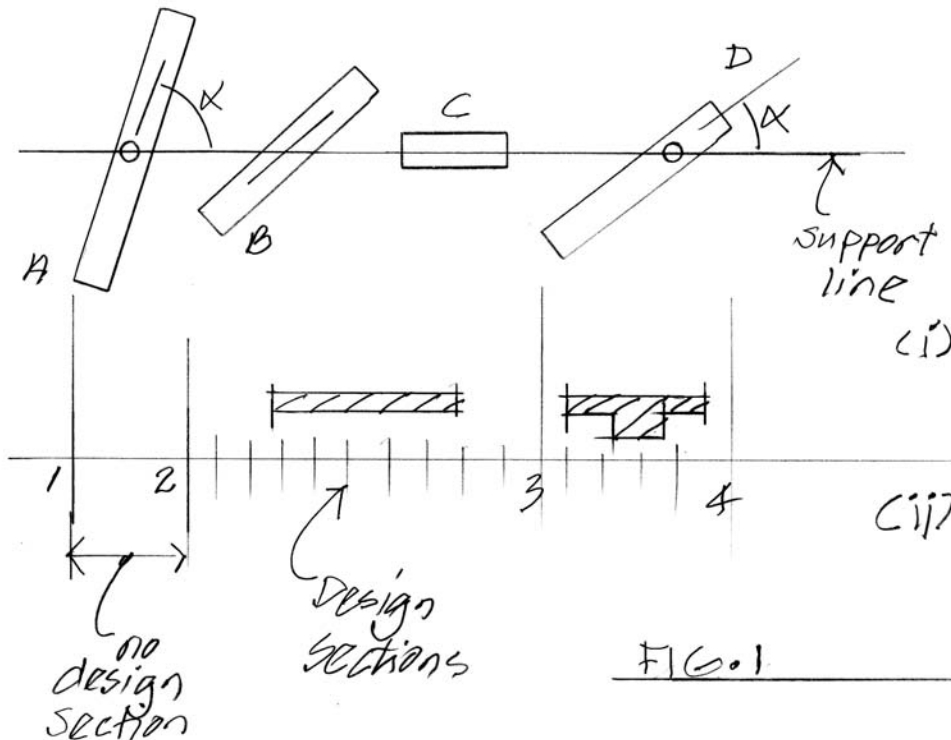

FIGURE 4

Other Structural Components
Drop caps, drop panels, slab bands, changes in slab thickness. and changes in elevation of structural components will be faithfully represented in the geometry of a design section and accounted for, regardless of their relation to support lines.

Change of Design Between the Two Modes of the Program
When changing the design mode from one mode of the program, "normal mode" to the other "waffle/joist" or vice-versa, it is essential to re-generate the design sections. For each of the modes, the program determines the contribution of the beams based on the requirements of the respective modes and performs the code check accordingly. In the general case, the location, and consequently the geometry of the automatic design sections generated for one mode can be different from those of the other mode.