A BRIEF DIALOG ON WOOD-ARMER AND TWISING MOMENTS IN FLOOR SLAB DESIGN[1]

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One method for floor slab design combines the twisting moment (Mxy) with the direct moments (Mxx, or Myy) to arrive at the "strength condition" moment, and use this moment to determine the required reinforcement. The method is referred to as "Wood-Armer" procedure. Technical Note TN433 outlines the features of this method in comparison with other schemes used for floor slab design. By way of a brief question and answer dialog, this Technical Note crystalizes the central differentiating feature between the "Wood-Armer" method and the other schemes. For background of the topic refer to ADAPT-TN 433.

BRIEF DIALOG

QUESTION 1
Is the explicit extraction and inclusion of twisting moments in "serviceability" design of slabs, namely deflection and stress computation necessary?

ANSWER 1
Answer: No. For "serviceability" check, where analysis methods based on plate theory are used, the contribution of twisting moment is implicitly accounted for. Explicit extraction of twisting moments is neither necessary, nor practiced. Also, it is not part of Wood-Armer procedure.

QUESTION 2
If the recognition and inclusion of twisting moments (Mxy) is not done explicitly for "serviceability" check of a floor slab, then where is it used? (The application is referred to as Wood-Armer procedure).

ANSWER 2
It is used for "safety check" of a floor slab, where the amount and location of reinforcement are determined

QUESTION 3
If the strength design of a floor is based on recognition of twisting moments (Mxy), and its implementation through a Wood-Armer type approach, will it lead to a "safe" design?

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ANSWER 3
Yes

QUESTION 4
Is the recognition of twisting moments, and their explicit implementation in design the “only” way to arrive at a “safe” design of floor systems?

ANSWER 4
No. There are many ways to design a safe floor system. Practically all other schemes of floor design are carried out without explicit recognition and implementation of twisting moment.

QUESTION 5
What is the principal differentiating point in recognition of Mxy and a reinforcement design based on Mxy (Wood-Armer) and other approaches of floor system design? Why not everybody uses “Wood-Armer” method of design?

ANSWER 5
The Wood-Armer procedure is based on assumptions that are neither realistic, nor lead to economical designs. Here are the reasons: (i) Wood-Armer procedure is based on a load path for the “safety” design of a slab that is “identical” to the slab’s uncracked elastic response – a slab’s failure takes place in the post-cracking regime. Wood-Armer used pre-cracking distribution of forces; (ii) the procedure provides the resistance (reinforcement) at the “exact location where demand is first generated,” namely the elastic response”; (iii) Wood-Armer approach does not account of the inherent “ductility” of reinforced concrete floor systems.

Other commonly used procedures recognize, and take advantage of post-cracking ductility of floor slabs. Using ductility, other commonly used procedures take advantage of the “redistribution” characteristics of a concrete floor and tweak a slab’s initial load path to one that can best suit the designer’s intent. The safety is based on the “design engineer selected load path.” In other words, the reinforcement for safety of a floor in non-Wood-Armer methods is based on a load path selected by designer, not the one dictated by the initial elastic response of a slab.

QUESTION 6
Which of the two schemes yields a more economical design?

ANSWER 6
For strength design, an economical design, defined as least use of material combined with ease of construction, takes advantage of ductility of a slab and relies on the selection of an advantageous load path. In practically all cases, such a load path relates to the post-cracking response of a floor and re-distribution of forces. In addition to least amount of reinforcement, selection of a suitable load path can lead to less material and labor for construction. This indirectly adds to economy of construction.

QUESTION 7
All this sounds very hypothetical. Can you give a simple example to better clarify the concept and difference?

ANSWER 7
Yes. Here is a simple example that illustrates the point.

Consider a single slab panel supported on four corner columns and subjected to a central point load P. It is required to reinforce the slab to safely carry to load. For clarity of illustration, without compromising the concept, selfweight and other loads are not considered (Fig. 1).

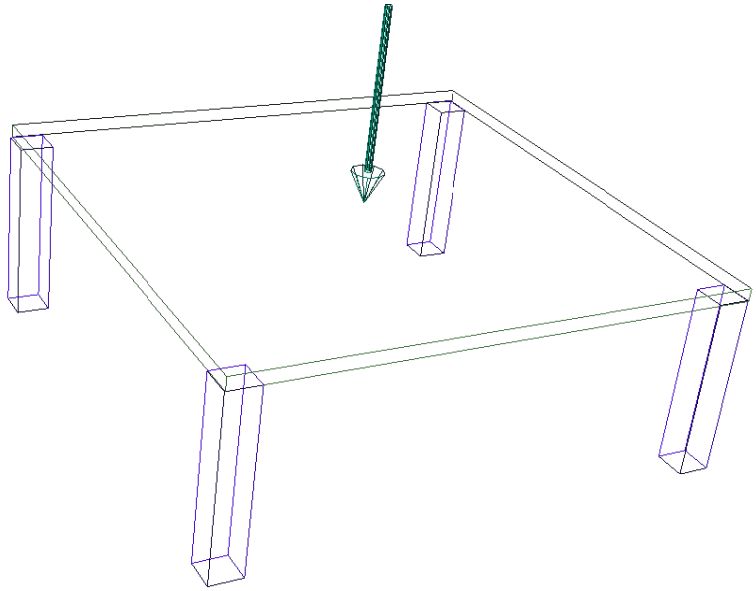


FIGURE 1 – Slab Panel on Corner Columns Subjected to a Central Point Load

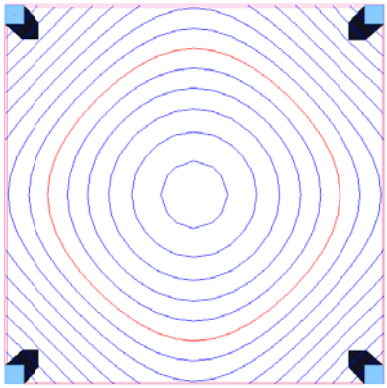
For safe transfer of load to the supports, one option is to consider a diagonal strip within the body of the slab as design "load path" (Fig. 2b). Considering the strip as a simply supported single span member between the diagonal columns, the demand actions (moments, shears) for the strip can be readily calculated and designed for. For the "safe" transfer of the load, the reinforcement will be limited to bars along the single diagonal. The outcome is a "safe" design.

(a) Slab under central load (b) Single diagonal strip

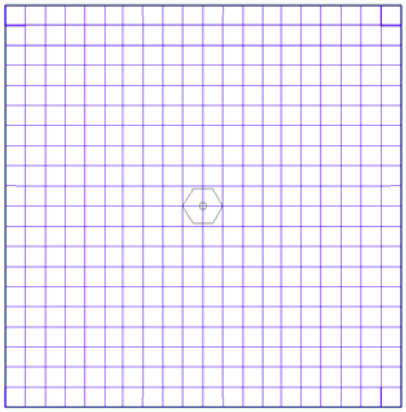
FIGURE 2 – Slab Panel with Central Load and a Single Diagonal Strip as Load Path

Using Wood-Armer approach, the load path governing the computation of reinforcement is the elastic response of the slab. The bending and twisting moments over the slab will have a distribution similar to Fig. 3a. Moments will be largest in the middle of the panel and the twisting moments largest near the

corners of the slab. The absolute sum of the bending and twisting moments, as required by Wood-Armer procedure leads to design-significant moment values over the entire floor system. The reinforcement required to resist the load will be bottom rebar in both directions over the entire slab and top rebar in both directions concentrated near the corners (Fig. 3b). To comply fully with the concept of Wood-Armer procedure, the spacing between the bars throughout the slab shall be maintained equal to or less than the slab thickness.



(a) Distribution of principal moments



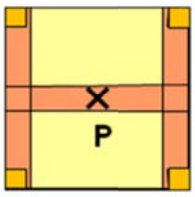
(b) Symbolic distribution of reinforcement

FIGURE 3 Distribution of Moments and Reinforcement Using Wood-Armer Procedure

QUESTION 8
Are there other options in selecting a load path for this structure?

ANSWER 8
Yes. There are many other options. The two images illustrated in Fig. 4 offer two configurations of slab strips that can be used as valid load paths for the safe transfer of load to the supports. In each instances, design engineers have the option to select a suitable load path.

(a) Intersecting diagonal strips



(b) Load path for reinforcement along the line of columns

FIGURE 4 – Alternative Design Strips for Safe Transfer of Load to Supports