CUSTOMER SUPPORT NOTE

Combinations and Wood – Armer Results

Note Number:	**CSN/LUSAS/1029**

This support note is issued as a guideline only.

LUSAS

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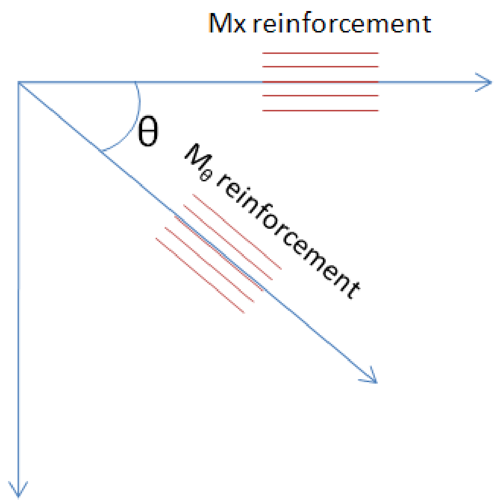
1. Introduction

The Wood-Armer facility of LUSAS provides an effective way of obtaining the design moments within the desired directions of reinforcing. These design moments are obtained by means of some nonlinear functions involving the moment field in the slab Mx, My and twisting moment Mxy. The present support note describes how LUSAS deals with the Basic Combinations of these results.

2. Description

When designing or assessing reinforced concrete flat slabs, the Wood-Armer facility of LUSAS provides an effective way of obtaining design moments within the desired directions of the reinforcement. The derivation of Wood – Armer results in LUSAS is based on the original set of equations developed by Wood (1968) and extender by Armer (1968). The outcome of the procedure is a set of moments, Top (hogging) (Mx(T) and Mθ(T)) and bottom (sagging) (Mx(B) and Mθ(B)), which can be used to design a two way reinforcement with an angle (θ) as illustrated below:



The procedure is using the moment field in the slab Mx, My and twisting moment Mxy:

1. **Top (Hogging) reinforcement**

$$Mx(T) = Mx + 2Mxycot\theta + Mycot^2\theta + \left|\frac{Mxy + Mycot\theta}{sin\theta}\right|$$

$$M\theta(T) = \frac{My}{sin^2\theta} + \left|\frac{Mxy + Mycot\theta}{sin\theta}\right|$$

If Mx(T) < 0 then Mx(T) = 0 and,

$$M\theta(T) = \frac{1}{sin^2\theta}(My + \left|\frac{(Mxy + Mycot\theta)^2}{(Mx + 2Mxycot\theta + Mycot^2\theta)}\right|)$$

If Mθ(T) < 0 then Mθ(T) = 0 thus,

$$Mx(T) = Mx + 2Mxycot\theta + Mycot^2\theta + \left|\frac{(Mxy + Mycot\theta)^2}{My}\right|$$

2. Bottom (Sagging) reinforcement

$$Mx(B) = Mx + 2Mxycot\theta + Mycot^2\theta - \left|\frac{Mxy + Mycot\theta}{sin\theta}\right|$$

$$M\theta(B) = \frac{My}{sin^2\theta} - \left|\frac{Mxy + Mycot\theta}{sin\theta}\right|$$

If Mx(B) > 0, then Mx(B) = 0 and,

$$M\theta(B) = \frac{1}{sin^2\theta}(My - \left|\frac{(Mxy + Mycot\theta)^2}{(Mx + 2Mxycot\theta + Mycot^2\theta)}\right|)$$

If Mθ (B) > 0, then Mθ (B) = 0 thus,

$$Mx(B) = Mx + 2Mxycot\theta + Mycot^2\theta - \left|\frac{(Mxy + Mycot\theta)^2}{My}\right|$$

Very often in design, a combination of loads is considered so the load effects on the structural members can be evaluated. When the Wood Armer moments are required from a Basic Combination, it is important to note that the derived components from each loadcase will not be added up in the combination. The reason for this is the non-linear nature of the Wood-Armer equations. Once calculated the Wood-Armer terms cannot be superimposed as this will lead to an unrealistic loading scenario which would never occur in practice. In other words, the raw Mx, My and Mxy stress resultant components that would correspond to a Wood-

Armer component, linearly superimposed in such a way are non-existent. Furthermore, the combination factors are applied to the "external loads" and thus they factor the direct resultant values Mx, My and Mxy. Factoring the load, will not factor the Wood Armer term by the same value because the relation between Mx, My and Mxy and Wood Armer is nonlinear.

3. Example

The following exemplary data clarifies the above statement:

Stress resultants output				
Loadcase	Node	MX	MY	MXY
UDL	21	-32.55	44.06	53.75
PointLoad	21	0.38	1.88	1.24
SW	21	-5245.44	6204.35	8036.62
Patch	21	-10.59	-37.20	-35.24
Total sum of above:	21	**-5288.20**	**6213.09**	**8056.37**

The leftmost column shows a set of loadcases which are considered in a Basic Combination for node 21 in the structure. The total sum of each of the stress resultants is given in the bottom row.

Now based on these results values for the Wood-Armer components will be calculated:

Wood - Armer Moment calculation					
Loadcase	Node	Mx(T)	My(T)	Mx(B)	My(B)
UDL	21	21.21	97.81	-86.30	-9.69
PointLoad	21	1.62	3.12	-0.44	0.00
SW	21	2791.19	14241.00	-13282.10	-1832.28
Patch	21	22.79	0.00	-45.83	-72.44
Total sum:	21	2836.80	14341.93	-13414.67	-1914.41
Combi 1	21	2768.18	14269.50	-13344.60	-1843.29

Using the equations earlier the Wood-Armer components are calculated for each of the loadcases. A total sum of the individual results is presented in the row coloured in red and the last row shows the true results for Combination 1. Clearly the total sum of individual components is higher for all of them but since it represents a non-realistic scenario cannot be used to compute the results in Combination 1. The basic combination will follow the logic where all stress resultants are summed up initially and a final derived Wood-Armer component is derived.

4. References

1. WOOD, R.H. The reinforcement of slabs in accordance with a pre-determined field of moments. Concrete. VBol.2, No.2 February 1968., pp69-79

2. ARMER, G.S.T. Discussion of reference 2. Concrete Vol.2, No.8. August 1968., pp319 - 320