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Cost Comparison and Performance of Different Types of Reinforcement for Two -way Slabs"

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Abstract

The effectiveness of the member should not take only from strength point of view, but also from other considerations. A cost analysis of two-way concrete slabs was studied. The variables were type of reinforcement (bars, fibers, and wire meshes), and cost of materials (including cost of labors).

The results indicated that the variation of steel content and labor prices seems to have a significant contribution in the cost objective function. Cost of ferrocemnt slab panels is high relative to its performance, while fibrous slab panels have more ductility with less cost.

Keywords : ***slabs, cost, ferrocement, steel fiber, two-way slab, labor cost, ductility, reinforced concrete.***

Introduction

Steel fibers and chicken wire meshes were more be used in two-dimensional thin members than other members (beams and columns) because of their effectiveness of them in resisting crack propagation and their contribution to increase stiffness and strength. Since fibers and wire meshes have nearly a planar distribution, and the forces have to be resisted in two directions[1].

The clear understanding of fiber and wire mesh reinforcement is relatively new. A number of investigation on various mechanical properties of concrete slabs reinforced with different types of reinforcement have provided technical information (flexural , shear ,deflections,...). Muspart[2] tested six full scale two-way simply supported concrete slabs reinforced conventionally. Jain and Kennedy [3] explained the yield criteria for coventionally reinforced concrete slabs. Ghalib[4] studied the effect of steel fiber on reinforced concrete slabs. Austriaco etal[5] showed the inelastic behavior of 39 ferrocement slabs. Al-Rifiai and Trikha [6]. and Aziz[7] presented the behavior of ferrocement slabs of different sizes subjected to distributed load.

Square precast slab elements made from steel fiber concrete have been used for the car park at London (Heathrow) airport[8]. The slab element dimensions were 1.1 x 1.1 x .064 m. A trial tests on panels 50 mm thick have also been done,It was shown that presence of

Fibers lead to a reduction in crack width at failure and increase in load carrying capacity.

Steel fibers and wire meshes will tend to find their major applications. The direct and indirect economic advantages can be gained from their properties, where their adaptability, convenience, and Labor savings can be fully exploited.

The effectiveness of members should not take only from a strength point of view (specially in the researches), but also from other considerations like serviceability, ductility, energy absorption, time of construction, and one of the most important factor is the cost of materials and Labors to obtain a better state between the performance of the structures and the cost. However, containing experience with steel fibers and wire meshes will increase the acceptance to growth, The economic of the them should become more favorable as the market expand since fiber production technology and efficiency will develop along a parallel path.

Cost of reinforced concrete members reported in the literature, related the problem with avariety of design variables. Iorns[9] study a cost comparison between structures either fabricated from ferrocement shortcrete laminating in precost concrete or from welded steel. CHakrabarty[10] oultines the design economics, cost function, and modeling of optimal design of reinforced concrete beams for different design conditions. Ezeldin and Hsu[11] showed the contribution of steel fibers to flexural and shear strengths of fiber reinforced concrete beams, and related this contribution of fiber to cost analysis of materials of the beams. Recently AL-Salloum and Siddiqi[12] presented a cost optimum design based on ACI code provisions of singly reinforced rectangular beams.

The main purpose of this study is to show the overall effect of the type of reinforcement on the strength, ductility, serviceability, and construction cost, and to obtain the effective performance related to the nature of the structure with optimum cost.

Research Significance

Steel fibers and wire meshes is slight increasingly used as a construction materials. This paper presents the effect of different types of reinforcement on the cost and efficiency of performance of two-way concrete slabs. The incorporation of cost factor in the design procedure is needed to determine the most economical situation satisfying structural and technical requirements.

Materials and preparation of specimens

The experimental program incorporated studies carried out with three different types of reinforcement :

1. Conventional bar reinforcement (plain) of 2.5 mm diameter, average yield strength of 269 MPa and modulus of elasticity of 200 GPa.

2. Galvanized Hexagonal woven wire mesh of 0.7 mm wire diameter, three volume fractions 0.138 x 0.08 , 0.218 x 0.218 , and 0.356 x 0.298 percent in both longitudinal and transverse directions were used to make ferrocement slabs S21 , S22 , and S23. They were equivalent in steel content to conventional reinforcement of slabs S11 , S12 , and S13 , respectively .The geometry and

dimensions of the wire mesh are shown in Fig.(1). The average yield and ultimate tensile stresses were 410 and 497 MPa, respectively. The modulus of elasticity in both longitudinal and transverse direction were equal to 104 and 69 GPa respectively[7].

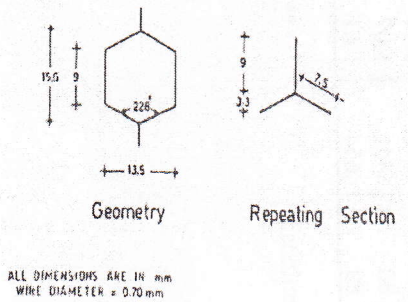

Fig.(1): Geometry and Dimensions of Wire Mesh Ref. [7]

3. Plain steel fibers of 20 mm length and 0.25 mm diameter (aspect ratio equal 80), three volume fractions 0.218 , 0.436 , and 0.654 percent were used to make three fibrous slabs S31 , S32 , and S33. They were equivalent in steel content to the conventional reinforcement ratio of slabs S11 , S12 , and S13 , respectively.

The plain bars were cut into the required lengths and positioned in the mould with specified spacing, see Table 1. While the ferrocement slabs (were taken from Ref. [7], the material properties, casting and testing conditions of the conventional and fibrous slabs were similar to those of the ferrocement slabs) consist of Hexagonal woven wire mesh layers cut to required size, held in position, and fixed to the sides of the mould by tightening wires.

The dry materials were first mixed thoroughly, then water was added, and mixing was continued until uniformity was achieved. When fibers were used, they were sieved continuously into the matrix while the mixer was in operation. The size of each mix designed to make one slab, three cylinders, and two prisms. The 850 x 850 x 35 mm (span-to-depth ratio is equal 23, which is allowed according to ACI- Code 318-95 [13]). Slabs were cast in nonabsobent oiled mould, and compacted carefully in three layers by a large vibrating table.

The control speciments of 100 mm diameter x 200 mm length cylinders, and 100 x 100 x 500 mm prisms were cast also with each slab to determine the compressive and modulus of rupture. The slab and control specimens were demolded after two days and cured for 28 days after which they were tested.

Testing equipment and procedures

A rigid steel frame was used to support the slab in both directions with clear spans of 800 mm. A steel box 800 x 800 x 250 mm which was opened from the upper and lower ends was used to hold a layer of sand 100 mm in thickness to distribute the load which comes on it from a hydraulic jack of 20 tons capacity. Details of loading arrangement are shown in Fig.(2).

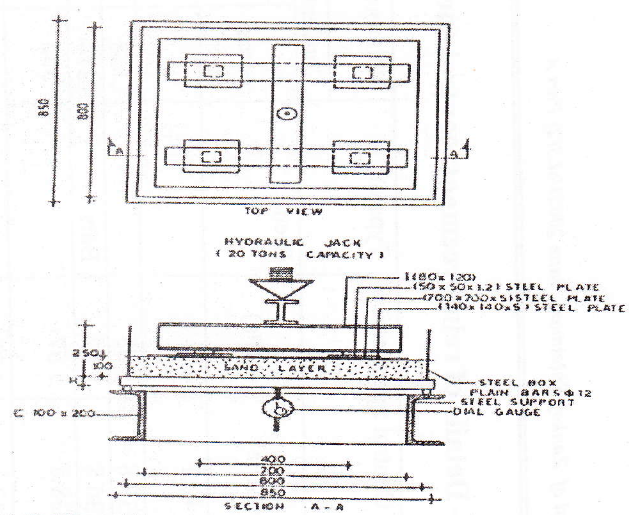

Fig. (2) : Loading Arrangement .

Table 1 – Details of reinforcement, control specimens, and materials cost per unit area of slabs.

Slob*	Control Specimens		Type of .	Reinforcement							Cost of ($/m^2)			Total
				Conventional			Wire mesh		Fiber					
No.	f_c' (MPa)	f_t (MPa)	Rienf.	ρ_L percent	ρ_t percent	spacing c.to c. (mm)	V_{fL} percent	V_{ft} percent	Aspect ratio	V_f percent	Reinf.	Mortor	Labor***	Cost ($/m^2)
S00	42.1	4.2										1.75	1.5	3.25
S11	37.8	5.05		.138	.08	101 × 175					0.84	1.75	2	4.59
S12	36.8	5.02	Bars	.218	.218	64 × 64					1.67	1.75	2	5.42
S13	38.8	5.57		.356	.298	39 × 47					2.51	1.75	2	6.26
S21	42.1	4.28	Chicken Wire Meshes				.138	.08			0.58	1.75	2	4.33
S22	43.2	4.36					.218	.218			1.16	1.75	2	4.91
S23	43.4	4.22					.356	.298			1.74	1.75	2	5.49
S31	39.5	10.1							80	.218**	0.54	1.75	1.5	3.79
S32	44	11.6	Fibers						80	.436	1.07	1.75	1.5	4.32
S33	49.1	13.4							80	.654	1.61	1.75	1.5	4.86

* Thickness of slab = 35 mm ; d = 32 mm   ** Randomly distributed in both directions.   *** Including cost of formwork

The load was applied in increments until failure. The central deflection, first cracking load and ultimate load were recorded.

Discussion of test results

All the slabs were tested under the same type of loading and the same boundary conditions.

First cracking load and ultimate carrying capacity :

As shown in Table 2 , with increasing the reinforcement ratio, fibrous slabs were more efficient than the other types in delaying the onset of first cracks. The increase in the first cracking load reached about 44.5 percent of the reference slab (i.e. slab SOO) for the largest volume fraction of fibers (i.e. slab S33). While the effectiveness of the bars and wire meshes in delaying the first cracks was less, reached 22.2 percent and 13.9 percent of the reference slab, respectively, for the largest steel content in the table.

The ultimate load is the peak point on the load deflection curve. As shown in Table 2, the conventional reinforcement was the most effective type of the reinforcement in increasing the ultirnate load capacity. The ultirnate carrying capacity increased by 126 , 239 , and 350 percent of the reference slabs for the steel contents .138 x .08 , .218 x .218 , and .356 x .298 percent (in both direction), respectively.

While the ferrocement and fibrous slabs had nearly the same ultimate resistance for the same rate of increasing of steel content in the Table 2.

Ductility

The main reason for studying ductility is that in some members the ductility may be far more critical than the strength considerations. The importance of ductility is increasing with an increased sophistication regarding limit and earthquake design, and with increasing use of concrete for nuclear reactor[1].

Ductility may be defined as the ratio of deflection at ultimate load to that at first visible crack (as used herein),or to the value at the design working load[14,15,1].

For all slabs, increasing in steel content led to decrease in central deflection for the same applied load, see Table 2 and Figs (3),(4),and (5). This means that the ductility decreases with increase in steel content. While the final deflection increased with increase in reinforcement ratio and according to this definition the final ductility increased with increase in steel content, since slabs in practice have a few amount of reinforcement content relative to beams, more under-reinforced member (i.e ρ is too less of ρ balance).

After onset of first cracks, the slabs reinforced with plain bars or fibers have undergoing large deformations before reaching the ultimate load, while the ferrocement slabs failed at the critical sections near the cracking load, as shown in Fig. (3) , (4) , and (5).

This means that the latter (ferrocement slabs) had too less ductility than the other two types, see Table 2.

Table 2– Durictitily (herein) : is the deflection at ultimate load to the deflection of reference slab (SOO Slab)

Slab No.	Type of Reinf.	Cost ($/m^2)	Wcr (kN)	Wu (kN)	Δcr (mm)	Δu (mm)	Percent of increase			Ductility*
							Cost	Wcr	Wu	
S00		3.25	18	18	1.25	1.25	0	0	0	1
S11	Bars	4.59	19	40.6	2.1	15.02	41.2	5.6	126	12
S12		5.42	20	61	1.52	22.7	66.8	11.1	239	18
S13		6.26	22	81	1.4	32.4	92.6	22.2	350	25.9
S21	Chicken wire	4.33	19	22.2	1.15	4	33.2	5.6	23	3.2
S22		4.91	20	30	1.05	6.04	51.1	11.1	67	4.8
S23		5.49	20.5	38.1	.96	7.5	68.9	13.9	112	6
S31	Fibers	3.79	18.4	22.03	1.62	11.5	16.6	2.2	22	9.2
S32		4.32	23.6	29.6	1.8	20	32.9	31.1	64	16
S33		4.86	26	37.8	2.05	22.6	49.5	44.5	110	18.1

Cost Comparison

The optimum design of any structure or members must not be taken cost and strength points of view, at the same tie. For example conventional and chicken wire meshes reinforcement require relatively high labor cost (input fixed the reinforcement in its place as specified), while fiber may significantly reduces the construction time and labor costs, especially in an area of high labor costs.

formulates a cost-design procedure for direct proportioning of different amount of reinforcement for concrete slabs .For the purpose of this study, the objective function is the combined cost of concrete, flexural reinforcement, and form cost (included cost of labor), expressed as a function of two design variables. These variables are the amount of reinforcement and the thickness of the slabs. The cost objective function (Z) per unit area of the slab will be given by the following expressions :

$Z = C_c t + C_s (A_{sl} + A_{st}) + C_u$ ...(1)

$Z = C_c t + C_{ch} N + C_u$ ...(2)

$Z = C_c t + C_f . V_f . t + C_u$ ...(3)

Equations (1),(2),and (3) are for concrete slabs reinforced with conventional, wire meshes, and steel fiber reinforcement, respectively.

Where :

t = thickness of the slab, mm.

A_{sl} = area of reinforcement in the longitudinal direction, mm2.

A_{st} = area of reinforcement in the transverse direction, mm2.

N = number of mesh layers.

V_f = volume fractions of fibers percent .

C_c = cost of concrete per unit area per unit thickness of the slab, $/mm/m^2 .

C_s =cost of steel per unit area of steel per unit area of the slab, $/mm/m^2 .

C_u = cost of forming (including cost of labor) per unit area of the slab, $/m^2 .

C_{ch} = cost of one layer of chicken wire mesh per unit area of the slab, $/m^2 .

C_f = cost of steel fiber per unit area per unit thickness of the slab, $/mm/m^2.

The cost of the materials, forming, and labor differ from a country to another. The calculations were made in U.S. dollars for market prices in united state as included in Refs. [11,16], see Table 1 for details. The following unit costs were used : $ 0.05/mm/m^2 ($ 50/m^3), $ 0.02/mm^2/m^2 for conventional steel, $ 2/m^2 for form work (including cost of positioning of reinforcement), $ 1.5/m^2 for form work (excluding cost of positioning), $ 7020/m^3 ($ 0.4/lb) for fibers, and $ 0.58/m^2 for a layer of chicken wire mesh. The relative value of unit cost could be used for situation, taken cost of steel, fiber, chicken wire, and formwork to concrete.

Effects of the type of reinforcement on concrete ductility, serviceability, and ultimate strength were included in this study as shown in Table 2. The table contains the values of cost per unit area of the slabs, the percent increase in the first visible cracking loads, ultimate loads, and times of increase in ductility. The following can be achieved from the inspection of tables:

1. The fiber panels delay the formation of the first cracking load by an amount of about 2.2 , 31.3 , and 44.5 percent of the reference slab (SOO), while the cost increased 16.6 , 32.9 , and 49.5 percent of the cost of the reference slab,

for slabs with V_f of 0.218 , 0.436 , and 0.654

2. percent, respectively. This means that less cost of members with higher cracking load, relative to other types.

2. The cost of ferrocement slabs was relatively high in comparison with fibrous or plain slabs. The percent increase in cost reached 33.2 , 51.1 , and 68.9 percent of that of the reference slab. While the increase in the first cracking load, ultimate load, and ductility of the ferrocement slabs were less than those of the fibrous slabs. (wire meshes may be more effective in other methods of construction or other structures).

3. The ductility of the fibrous slabs 9.2, 16 and 18.1 times the ductility of reference slab, while the increase in cost were 16.6, 32.9 and 49.5 percent of the reference, for lower, medium, and higher volume fraction (Herein used), respectively. For conventional slab the ductility equal to 12, 18 and 25.9 percent for S11, S12 and S13 with cost increase 41.2, 66.8 and 92.6 percent , respectively.

4. If the ductility or serviceability (cracking load) for example, is the major limitation in the design, the best panel situation (according to specimens tested in this research) could be chosen built on lower cost, was fibrous slab S33, the cost increase reached 49.5 percent of the reference slab with 44.5 percent increase in first crack load and 18.1 time the ductility of the reference.

Sensitivity analysis was performed to establish the effect of parameter's variation on the cost objective function values, as shown in Figs.(6),(7) and (8). The included parameters were type of reinforcement and concrete cost($ 50/m^3, $ 100/m^3, or $ 150/m^3). The results of the analysis indicate that the labor cost has significant effect on the cost objective function. .

If conventional bars with fibers or bars with wire meshes are used in the slab to obtain the optimum use of the steel content, the combined objective function (Equations (1)+(2) or (1)+(3)) can be used directly).

Conclusion

1. Fibers reinforcement for slabs were more efficient than bars and wire meshes in delaying the onset of first cracks.
2. Fibers and conventional bars have a significant role in enhancing the ductility of the slabs. The ductility reached 18.1 and 25.9 times the ductility of reference slab(i.e SOO) for slabs with higher steel content, with increase in cost relative to the reference slab of about 49.5 and 92.6 percent, respectively.(i.e. the fibrous slab has too less cost).
3. The variation of steel content, type, and labor prices seems to have a significant contribution in the cost objective function.
4. Further studies are required to include the combined effect of the conventional bars with fiber or the conventional bars with wire meshes in slab panels to obtain the most optimum use of reinforcement, gained economic solution.
5. In each research cost of the materials and labor must take into account with other limit state consideration (first crack, ultimate load, deflection, ductility, energy observation, ...) because the latter did not give ample information to the designer.

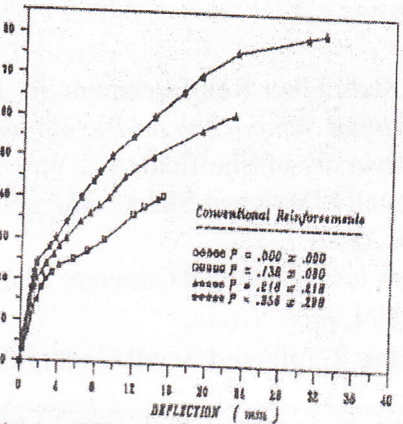

Fig. (3):Load - defliction curves for conventional slabs .

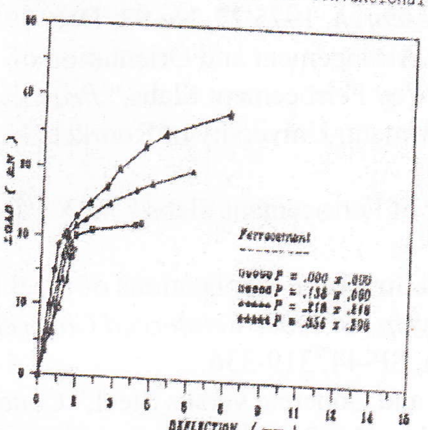

Fig. (4): Load - defliction curves for ferrocement slabs Ref.[7]

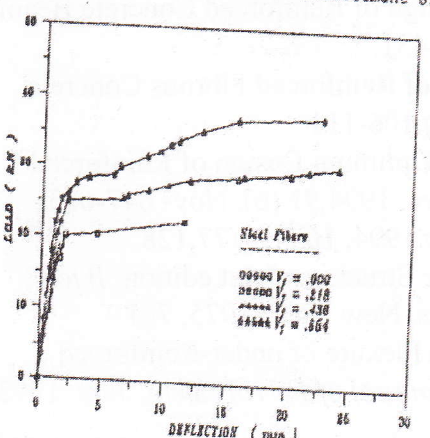

Fig. (5): Load - defliction curves for fibrous slabs .

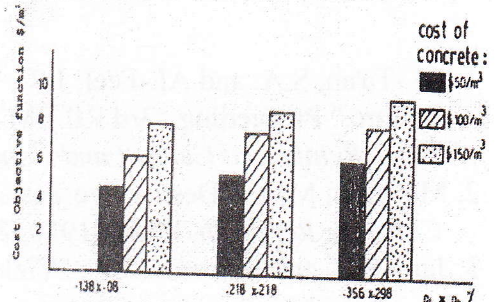

Fig.(6) Sensitivity of concrete cost, for conventional reinforced slabs.

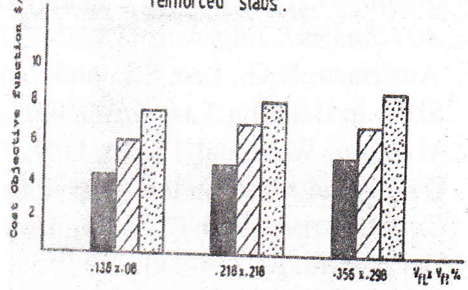

Fig.(7) Sensitivity of concrete cost, for ferrocement slabs.

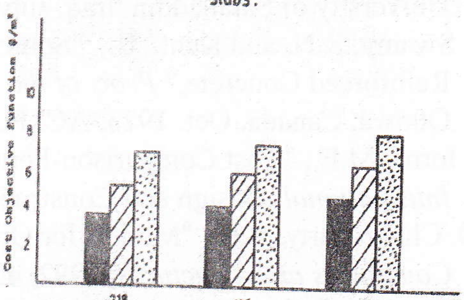

Fig.(8) Sensitivity of concrete cost, for fibrous slabs.

References

1. AL-Ta'an, S.A. and AL-Feel, J.R., "Role of Steel Fiber Reinforcement in Flexural Failure," Proceeding, 3rd RILEM *Introductional Symposium on Developments in Fiber Reinforced Cement and Concrete*, University of Sheffield, V.2, July 1986.
2. Muspartt, M.A., "Destructive Tests on Rationally Designed Slabs," *Magazine of Concrete Research*, March,1970,.*22*, No.70,.25-36.
3. Jain, S.C. and Kennedy, J.P., "Yield Criterion for Reinforced Concrete Slabs," *Journal of the Structural Division*, March 1974, pp.631-644.
4. Ghalib, M.A., "Moment Capacity of steel Fiber Reinforced Small Concrete Slabs," *ACI Journal*, July-Aug 1980.247-25.
5. Austriaco, N.G., Lee, S.L. and Pama, R.P., "Inelastic Behaviour of Ferrocement Slabs in Bending," *Magazine of Concrete Research*, 1975,**27**, No.93, Dec, 193-203.
6. AL-Rifai, W.N. and Trikha, D.N., "Effect of Arrangement and Orientation of Hexagonal Mesh on the Behaviour of Two-Way Ferrocement Slabs," *Proc. 3rd. Int. Conf. Ferrocement*, Civil Engineering Department, University of Roorkee, New Delhi,1988, pp.219-233.
7. Aziz, I.H., "Flexural Strength and Behaviour of Ferrocement Slabs," *M. Sc. Thesis*, University of Salahaddin, Iraq, July 1994.
8. Swamy, R.N. and Kent, B., "Some Practical Structural Applications of Steel Fiber Reinforced Concrete," *Proc. of the Intern. Symp. on Fiber Reinforced Concrete*, Ottawa, Canada, Oct. 1973, ACI Publication, SP-44, 319-336.
9. Iorns, M.E., "Cost Comparison-Ferrocement and Concrete versus Steel," *Concrete International*, Design and Construction, 11, Nov.1983, **5**,45-50.
10. Chakrabarty, B.K., "Models for Optimal Design of Reinforced Concrete Beams," *Computers and Structures*, 1992, **42** (3), 447-451.
11. Ezeldin, A.S., and Hsu, C.T., "Optimization of Reinforced Fibrous Concrete Beams," *ACI-Structural Journal*, 1992, **89** (1),106-114.
12. AL-Salloum, Y.A. and Siddiqi, G.H., "Cost-Optimum Design of Reinforced Concrete Beams," *ACI-Structural Journal*, Dec. 1994,**91** (6), Nov- 647-655.
13. ACI 318 M-95", *Concrete International*, Dec.1994, **16** (12), 77,128.
14. Parl, R. and Paulay, T., "Reinforced Concrete Structures," 1st edition, *Wiely interscience Publication*, John Wiley and Sons, New York, 1975, 761
15. Prawel, S.P. and Reinhorn, A., "Properties in Flexure of under-Reinforced Ferrocement Panels in Two-Way Bending," *Journal of Ferrocement*, July. 1992,**12** (3). 237-250.
16. Gastro, J. "Ferrocement Roofing Manufactured on a Self-Help Basis," *Journal of ferrocement*, No.1, July. 1977(7), 17-27.

یكراوی تیچون و كاركردنی بنمیچی كۆنكریتی بەچەن چۆرە شیشی بەندكراو بەدوولا

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پوختە

چوستی هەر ئەندامێكی هەر تەلارێك تەنها لەسەر بەرگرێكەی ناوەستێت وگەلی هۆكار هەن كەكار لەو چوستی‌یە دەكەن.

لەم لێكۆلینەوە برێ تێچوونی بنمیچی كۆنكریتی بەندكراو بۆ دوو لا شیكراوەتەوە. لەتۆژینەوەكەدا ئەو هۆكارانە جۆری شیش (شیش ، ریشالی پۆلایین و وایەری چنراو) و تێچونی مادەكان (تێچونی كرێی كرێكار دەگرێتەوە) لەبەر چاو گیراوە.

لێكۆلینەوەكە وادەری دەخات كەهۆكاری برِی ئاسن و كرێی كرێكار دەوری سەرەكی هەیە لەئەنخشەی تێچوندا.
هەروەها تێچوونی ئەو بنمیچانەی كەشیش تەندكراون بە وایەری ئاسنی چنراو بەرزە لەكاتێكدا كەبنمیچە شیش بەند كراوەكان بە ریشالی پۆلایین ئەرمیان بەرزەو تێچوونیان كەمترە.

مقارنة الكفة للبلاطات الخرسانية المسلحة بالاتجاهين وبمختلف أنواع التسليح

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الخلاصة

كفاءة أي عضو إنشائي يجب أن لا تاخذ المقاومة فقط بنظر الاعتبار، لذا تمت دراسة تحليل كلفة البلاطات الخرسانية المسلحة بالاتجاهين، وشملت المتغيرات على : نوع التسليح (القضبان) الألياف الفولاذية، والأسلاك المحيوكة)، كلفة المواد (من ضمنها كلفة الأيدي العاملة)، صلاحية التشغيل، والمقاومة القصوى). بينت الدراسة بأن المتغيرات، كمية الحديد ونوعها وكلفة الأيدي العاملة لها دور أساسي في دالة الكلفة (Cost objective function) وكانت كلفة تسليح البلاطات بأسلاك مشبكات الحديد عالية (في النماذج المستخدمة في هذا البحث) نسبة الى الأداء الوظيفي للعضو، بينما البلاطات المسلحة بالألياف القصيرة لها مطيلة عالية وبكلفة قليلة نسبيا.

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