Design Aids For Precast Ordinary Reinforced and Prestressed Concrete Hollow-Core Slabs

Hussam Ali Al-Mamuree
Al-Mussiab Technical College

Abstract

The application and design of precast, prestressed hollow core slabs is similar to that of other prestressed members. However, there are situations which are unique to hollow core slabs either because of the way the slabs are produced or because of the application of the slabs. For special situations, hollow core producers have developed design criteria and conducted in house testing to verify that their approaches are valid. In fact, there is consistency between the many types of hollow core slabs available.

This research work is intended to cover the primary design requirements for hollow core floor and roof systems. Where, it was carried out by computerized finite element model for the hollow-core slab, ordinary reinforced and prestressed. On which a design aids were prepared and arranged in a manner to be used in simple way. All reasonable care has been used to verify the accuracy of material contained in the research. However, the obtained data should be used only by those experienced in structural design and should not replace good structural engineering judgment.

In this study, charts for the design of one and two-end continuous hollow-core slabs were developed by the using of analysis and redesign by the finite element technique. These charts enable to find the required moment capacity at supports and the moment redistribution from supports to be determined for a desired increase in span length.

الخلاصة

استخدامات وتصميم السقوف المجوفة جاهزة الصب , إن كانت ذات تسليح اعتيادي أو مسبقة الإجهاد, يتشابه كثيراً للأعضاء الإنشائية الأخرى المرادفة لها. على الرغم من وجود مواقف فريدة يتنسب و يتعين استخدام هذا النوع من السقوف نظراً لطريقة تصنيعها أو طريقة عملها موقعياً. ومن هذا المنطلق ولمراعاة تلك المواقف التي تنسب استخدام السقوف المجوفة, فأن أساليب و طرق تصنيعها قد طورت مع تطوير تقنيات التصميم و آلياته مع محدداته و طبقت على تجارب عمليه لتحقيق فعالية هذا النوع من السقوف, وخاصة مع وجود ترابط وتماسك قوي لقوام تلك السقوف المجوفة مع بعضها و خدمتها للغرض الموجودة لأجله.

هذا البحث يهدف إلى تغطية أسلوب التصميم الأولي و متطلباته للسقوف المجوفة و ما ينعكس عليه من أرضيات للطوابق الأخرى. حيث تم أجراء متطلبات البحث ببرمجة موديل عددي باستخدام طريقة العناصر المحددة وتطبيقها على السقوف المجوفة ذات التسليح الاعتيادي و كذلك مسبقة الإجهاد. حيث تم إعداد مخططات تصميمية معدة بأسلوب سهل الاستخدام مع مراعاة اخذ جميع متطلبات التصميم و تشابه الموديل الرياضي لواقع حال النماذج المدروسة. مع التأكيد لكون المخططات لا تلغي حكمة التصميم الهندسي المتقن.

كذلك تمت دراسة استمرارية السقوف المجوفة من جانب واحد أو جانبين من خلال الموديل الرياضي و استمرارية تكرار التحليل الإنشائي لنماذج مختلقه الأبعاد و الأطوال من جانب و حالات الإسناد من جانب أخر. لاستحصال قيم القصوى للعزوم و تغيراتها من خلال زيادة الفضاءات المدروسة.

1. Introduction

Hollow-core is a precast prestressed concrete slab, which is suitable for use in a range of commercial buildings, and in all types of housing. Hollow-core can fit easily into any structural system, whether it is steel, in-situ, precast, or concrete masonry. The advantages of Hollow-core are as follows.

- High loading capacity, can be used over long span's.
- Quick installation.
- Efficient building system.
- Environmentally friendly system.

- Provides immediate safe working platform.
- Excellent sound and vibration barrier.
- Health & safety benefits, with a reduction in the required number of personnel on site.
- Generally does not require propping.
- All Hollow-core units meets minimum fire safety requirements to comply with building regulations.

Further Information:

- Is manufactured at 1200mm wide slabs, and can be cut to any width to suit all applications.
- Available in depths of 150,200,250,300,400, and 500mm, as shown in Fig. (1A).
- The continuous voids in the Hollow-core reduce its weight and costs.
- Oran-Precast can provide span's up to 19m for 500mm deep Hollow-core.
- Features like voids and notches can be incorporated into the design of the units.
- The units are produced utilizing modern manufacturing techniques and facilities, which allows the company to deliver the highest quality standards demanded in construction practices.

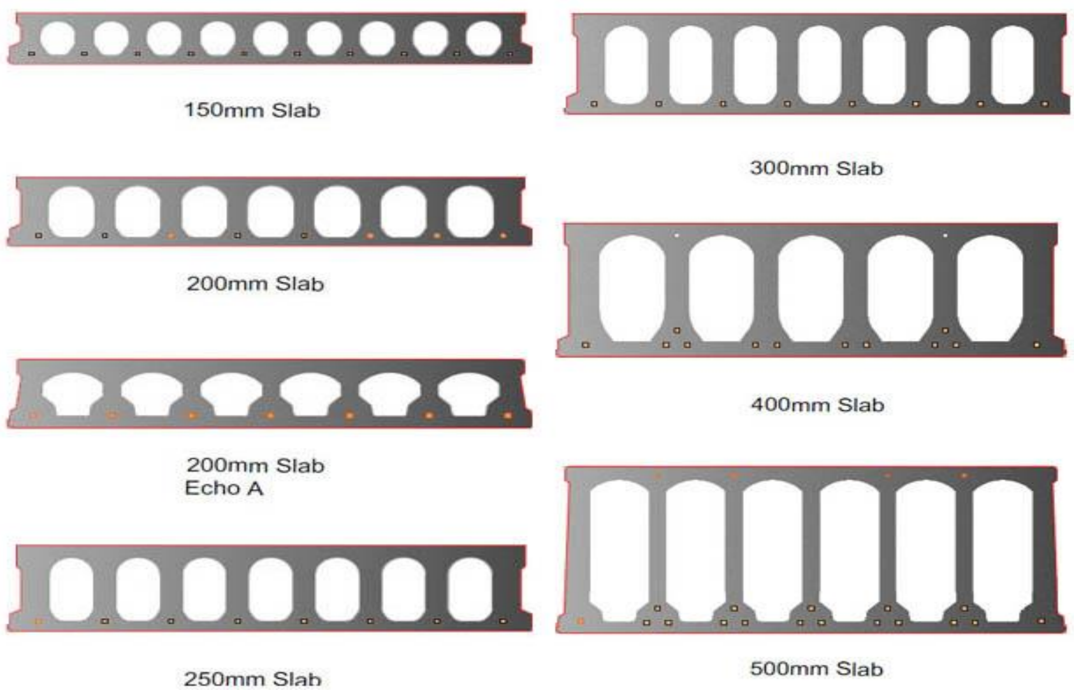


Fig. (1A) General available Types of the hollow-core slabs sections as in [PCI Manual, 1988].

2. Literature Review

Precast, prestressed hollow-core slabs are the most commonly used precast concrete components in low and high rise building construction. They are usually used as simply supported elements with structural topping concrete provided over supports to serve as structural integrity ties and diaphragm connections. [PCI Manual, 1988]

In the past two decades, a significant amount of research has been carried out to investigate the shear resistance of hollow-core slabs [Pisanty, 1992, Ueda, 1991], special reinforcement for end supports [Mejia-McMaster, 1994], slab response to concentrated load [Stanton, 1987, 1992], behavior under edge loads [Aswad, 1992], and composite action with topping concrete [Scott, 1973]. However, very little published information exists on continuity in hollow-core slabs and this information was limited to the use of separate dowel bars grouted into drilled holes in precast slabs [Rosenthal, 1978], and the use of prestressing strands in the cross filled with concrete [FIP Technical report, 1992].

Although the PCI Hollow-Core Design Manual acknowledges that continuity over supports results in better control of superimposed load deflections and a lower requirement for positive moment capacity, this is usually not exploited in hollow-core slab design, mainly because of the lack of design aids.

The main objective of this study is to develop charts for the design of connections in continuous hollow-core slab construction. A set of formulas relating the increase in span capacity of hollow-core slabs, moment redistribution allowed at supports, and the design mid-span and supports moments of slab, is first derived theoretically. These relations are then shown in a graphical form to facilitate the design process.

3. What Architects Should Know about Hollow Core Slabs

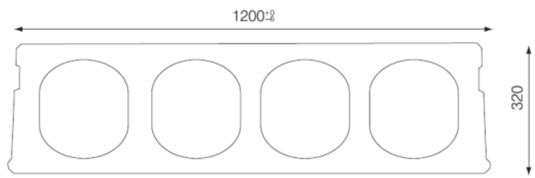


Fig. (1B) Sample from the types of the hollow-core slabs sections.

Applications

Hollow core slabs can be used for most applications requiring a floor or roof system. Schools, office buildings, condominiums, hotels, senior citizen's apartments, commercial buildings, residential dwellings, houses of worship, nursing homes and educational facilities are all ideal applications. For hotels, motels and apartments the hollow-core slabs are oriented to either span between load bearing shear walls or to span from the central corridor to the exterior walls. Slabs can be cantilevered up to 1.5 m.

Sizes

Hollow core is economical. Modular precast concrete floor and roof slabs are machine manufactured under controlled conditions in modern precast plants. Most slabs are 1220 mm nominal width and 203 mm deep – other sizes are available for special applications [152 mm, 254 mm, 305 mm, 355 mm]. – consult your local CPCI member for available sizes.

Manufacturing

Hollow core slabs are made on long-line casting beds and cross-cut at 900 to the exact length for each project. Angle cuts are possible but cost more. It is desirable to have the plan dimensions fit the slab module, typically 1220 mm. Non-module plan dimensions can be accommodated using partial width slabs.

Prestressing

Hollow core slabs are prestressed. This means longer spans, shallow depth and the ability to carry heavy loads are easily accommodated. This also means better space planning and a lower floor/floor height. Lengthening the span is economical with fewer slabs to make and install. Maximum span/depth ratios of 45 are recommended for floors. A 203 mm slab can span up to 9 m depending on the loading. A 305 mm slab can span up to 14 m depending on the loading.

Use of Slab Voids

Hollow core is cast with continuous voids to reduce weight and cost and, and as a side benefit, for use to conceal electrical wiring or mechanical ducts. When properly coordinated for alignment, the voids in hollow core slabs can be used for electrical or mechanical runs. For example, routing of a lighting circuit through the cores can allow fixtures in an exposed slab ceiling without unsightly surface mounted conduit. Slabs detailed to distribute heated air through the cores can be used as the thermal mass in a passive solar application.

Load Distribution

Hollow core slabs are designed as individual, one way, simple span slabs. When the slabs are installed and grouted together at the keyways, the individual slabs become a system that behaves similarly to a monolithic slab. A major benefit of the slabs acting together is the ability to transfer forces from one slab to another. In most hollow core slab deck applications, non-uniform loading occurs in the form of line loads, concentrated loads, or load concentrations at openings. The ability of individual slabs to interact allows these load concentrations to be shared by several slabs. The ability to distribute loads among several slabs has been demonstrated in published tests.

4. Constitutive Relationships and Finite Element Formulation

Reinforced and prestressing concrete, are usually simulated by considering the constitutive relations of its constituents independently, because each of concrete and prestressing and reinforcing steel have very different material properties. The *20-noded isoparametric brick element* was used to model the concrete and both prestressing and reinforcing bars was idealized as axial members embedded within the concrete elements, as shown in **Fig. (2)**.

The behavior of concrete in compression was simulated by an ***elastic-plastic work hardening model*** followed by a perfectly plastic response, which is terminated at the onset of crushing as shown in **Fig. (3)** [Al-Shaarbaf, 1990]. In tension, a ***smeared crack*** model with fixed orthogonal cracks was used with the inclusion of models for the retained post-cracking stress and reduced shear modulus as shown in **Fig. (4, and 5)**.

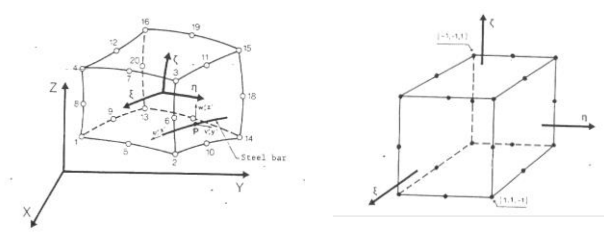
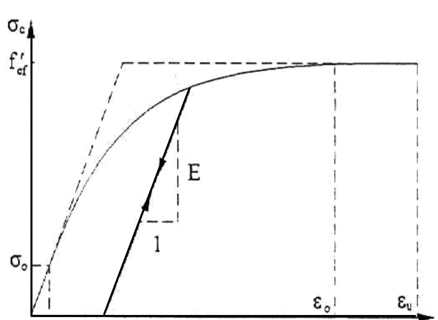
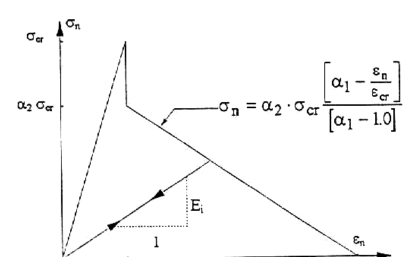


Fig. (2). The 20-noded isoparametric brick element.





Slenderness of steel allows generally assumed to be capable of transmitting axial force only. An elastic linear work hardening model is used to represent the uniaxial stress-strain behavior of the reinforcement, as shown in **Fig. (6)** [Al-Shaarbaf, 1990].

The nonlinear equations of equilibrium were solved using an incremental-iterative technique operating under load control. The ***standard and modified Newton-Raphson*** methods were used as solution algorithms [Al-Shaarbaf, 1990].

Full details of the constitutive models and the finite element formulation can be found in reference [Mohammed, H. 2005]

5. Outline of the Adopted Computer Program

In the present study, the computer program 3DNFEA (3-DimensionalNon-linear Finite Element Analysis)which was originally developed by Al-Shaarbaf [Al-Shaarbaf, 1990] has been used. This program was constructed mainly for the non-linear analysis of reinforced concrete members under general three-dimensional state of loading up to failure. In this study, the computer program 3DNFEA has been adopted for analyzing prestressed concrete beams. It was been modified to be suitable for analyzing prestressed concrete beams.

6. Basis for Design Charts

As indicated earlier, two major benefits results from designing for moment continuity over supports in hollow-core slab construction. First, this practice leads to an increase in the span capacity of hollow-core slabs for given design load. Second, it helps to reduce the deflections of the slabs. The first aspect is employed in the development of design charts for the design of moment continuity over supports.

6.1 Design for Two-End Continuous Span

Fractional Increase in span capacity – In hollow-core slab design, the span capacity, $\boldsymbol{L}_o$, corresponding to a safe superimposed load is usually specified by the manufacturers or in handbooks for simply supported end conditions. Given the self-weight of the slab, the design uniform load, ***W***, on the slab can be established and the nominal moment capacity, M_s, of the slab corresponding to the span is :

$$M_s = \frac{1}{8} W L_o^2 \quad (1)$$

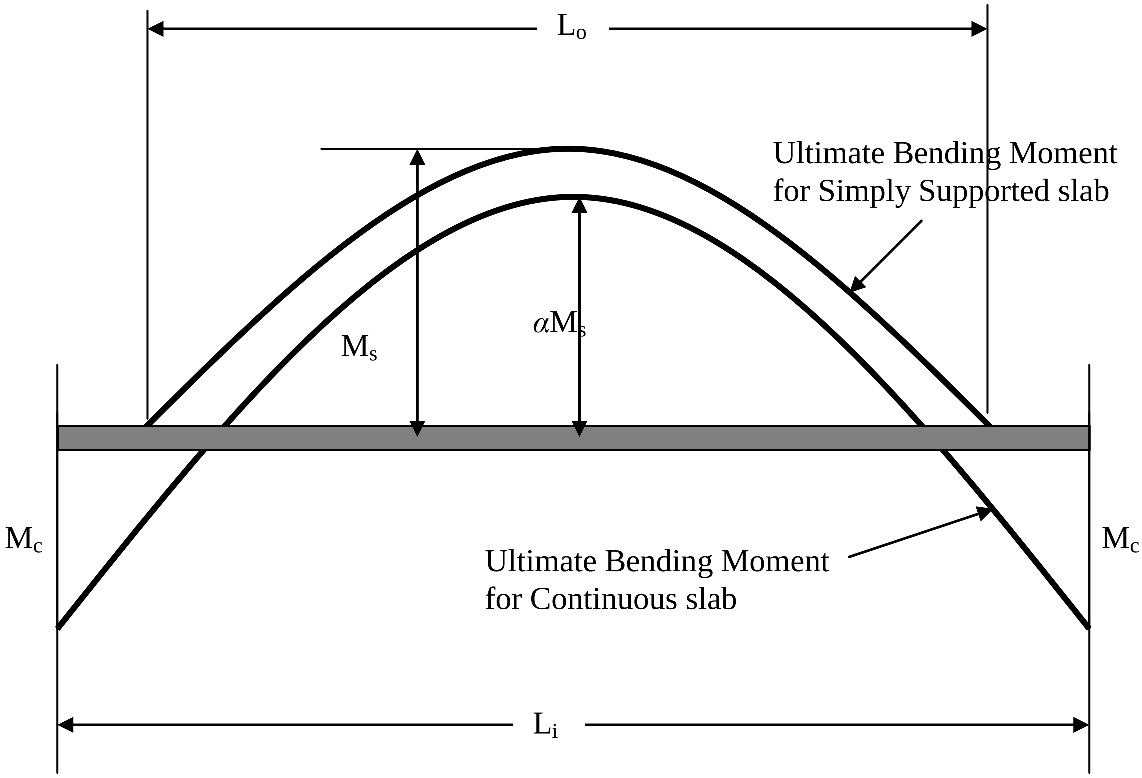


Fig. (7) Increase in span capacity of hollow-core slabs due to continuity at supports.

suppose that the same slab was designed as a two-end continuous slab with ultimate support moment M_c at each end (Fig. 7) and mid-span moment αM_s, where α is the ratio of the design mid-span moment to the nominal moment capacity of the hollow-core slab [Kiang-Hwee, 1996]. Here, the coefficient α denotes the degree to which the nominal moment capacity of the slab is being utilized in continuous construction and has a value between 0 and 1 inclusive. For the same design uniform load ***W***, the continuous slab would be able to span a length L_i given by:

$$\alpha M_s + M_c = \frac{1}{8} W L_i^2 \quad (2)$$

introducing $\beta = M_c / M_s$ and eliminating ***W*** from Eqs. (1) and (2) leads to:

$$\frac{L_i}{L_o} = \sqrt{\alpha + \beta} \quad (3)$$

It is seen from Eq. (3) that if $\alpha + \beta > 1$, L_i will be larger than L_o; and an increase in span is achieved.

Under elastic conditions, however, the fixed end moments would have been M_f where:

$$M_f = \frac{1}{12} W L_i^2 \tag{4}$$

thus, the moment M_f at the support has been assumed to be redistributed at ultimate such that:

$M_c = (1-R) M_f$

Where R is the percentage of moment redistribution from the supports, of which a value of up to 30 percent is usually allowed in design[Kiang-Hwee, 1996].

Substituting Eqs. (4) and (5) into Eq. (2) and rearranging for L_i gives:

$$L_i = \sqrt{\frac{24\alpha M_s}{(1+2R)W}} \tag{6}$$

from Eq. (1):

$$L_o = \sqrt{\frac{8M_s}{W}} \tag{7}$$

hence, the fractional increase in span capacity can be expressed as:

$$\frac{dL}{L} = \frac{L_i - L_o}{L_o} = \frac{\sqrt{\frac{24\alpha M_s}{(1+2R)W}}}{\sqrt{\frac{8M_s}{W}}} - 1 \quad = \quad \sqrt{\frac{3\alpha}{1+2R}} - 1 \tag{8}$$

Eq. (8) shows that an increase in span is possible only if $\alpha > (1+2R)/3$.

Required Moment Resistance at Supports – Substituting Eq. (4) an d (6) into Eq. (5) gives:

$$M_c = \frac{2(1-R)\alpha M_s}{1+2R} \tag{9}$$

or, noting that $\beta = M_c / M_s$:

$$\beta = \frac{2(1-R)}{(1+2R)} \alpha \tag{10}$$

Eqs. (8) and (10), which respectively relate the fractional increase in span dL/L and the ratio β to the percentage of moment redistribution from supports R and the ratio α.

For the case where α=1 and $R \leq 0.3$, it is seen that adequate span length of hollow-core slabs can be increased by between 37 and 70 percent. If the full positive moment capacity of slab is not used (that is, α<1), then the fractional increase in span capacity due to the provision of continuity at the supports would be correspondingly less [Kiang-Hwee, 1996].

6.2 Design for One-End Continuous Span

It can be, shown in similar manner that if the slab is designed as a one-end continuous slab, the increased span capacity, L_i, would be given by:

$$\frac{L_i}{L_o} = \sqrt{\alpha + \frac{\beta}{2}} \qquad (11)$$

where L_o is the span capacity for a simple-support slab design, and α and β are the ratios of the design mid-span moment and support moment at the continuous end, respectively, to the value of M_s, which, as defined earlier, is the nominal moment capacity with respect to L_o.

the fractional increase in span capacity, ***dL/L***. and the value of β can be shown to be related to α and R by:

$$\frac{dL}{L} = \frac{L_i - L_o}{L_o} = \sqrt{\frac{2\alpha}{1+R}} - 1 \qquad (12)$$

and

$$\beta = \frac{2(1-R)}{(1+R)}\alpha \qquad (13)$$

Eqs. (12) and (13) are depicted graphically in Fig. 3.

An increase in span capacity is achieved only if α ***> (1+R)/2***.

For the case where α=1 and ***R***≤30 percent, the increase in span capacity varies from 24 percent to 41 percent.

6.3 Use of Design Charts

with the aids of the finite element idealization and modeling, for the cases of hollow-core slabs, a design charts obtained in a manner proving the above derivation. Considering all parameters needed to tracing the above derivation and taking several cases study, to resulted an identical design charts. Also an increase in span capacity of hollow-core slabs by between 37 and 70 percent for the case where α=1 and ***R***≤0.3, for two-ended continuous span, and also an increase about 24 percent to 41 percent obtained for one-end continuous span.

The design charts given in Figs. (8, 9, 10 and 11) allow the value of β and, hence, the required moment resistance M_c at the connection and the corresponding increase in span capacity of the slab to be determined from specified values of ***R*** and α. Once the value of M_c is determined, the required reinforcement ratio, A_s/bd at the connections over the supports can be worked out from conventional section analysis or from deign aids for flexure.

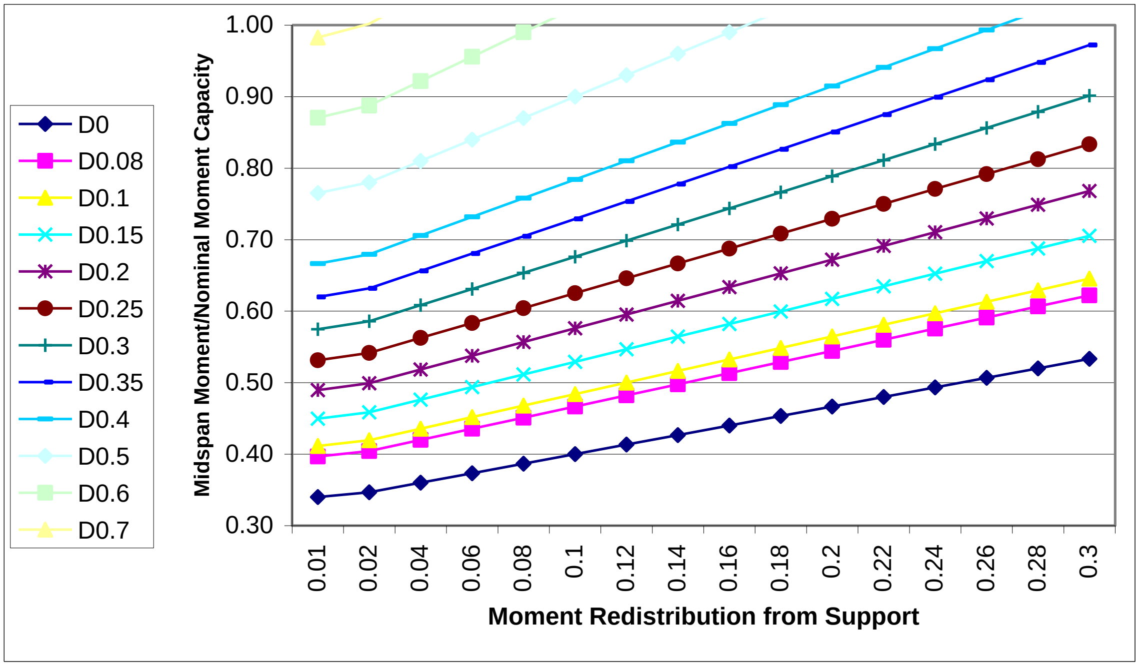


Fig. (8) Design Chart for two-end continuous span (Various *dL/L*)

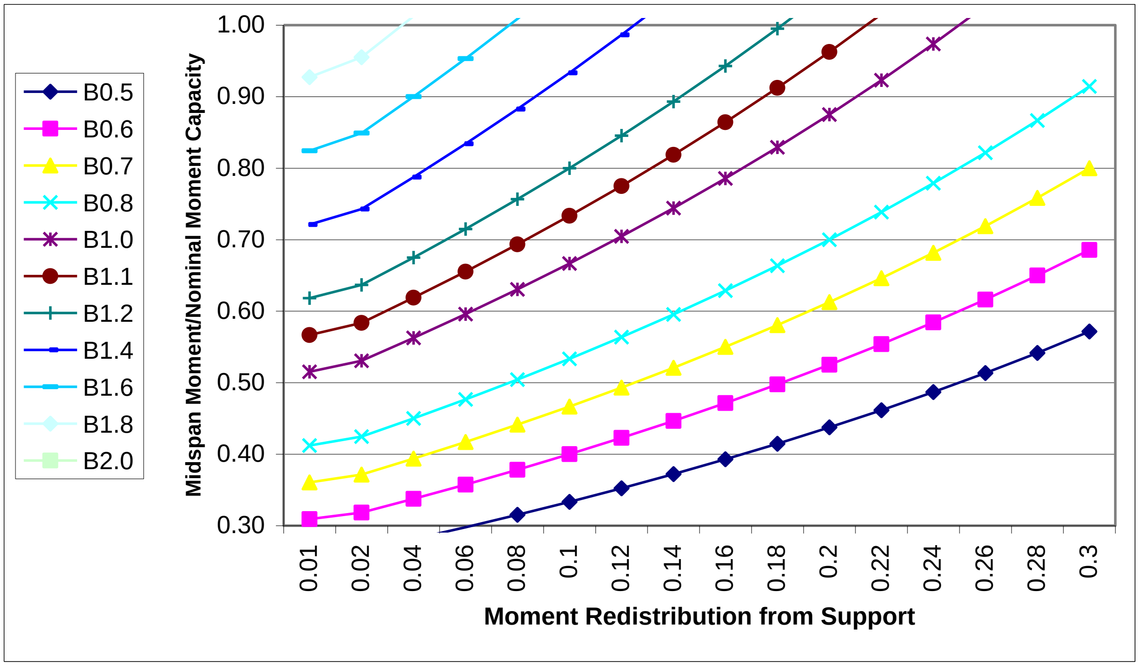


Fig. (9) Design Chart for two-end continuous span (Various β value)

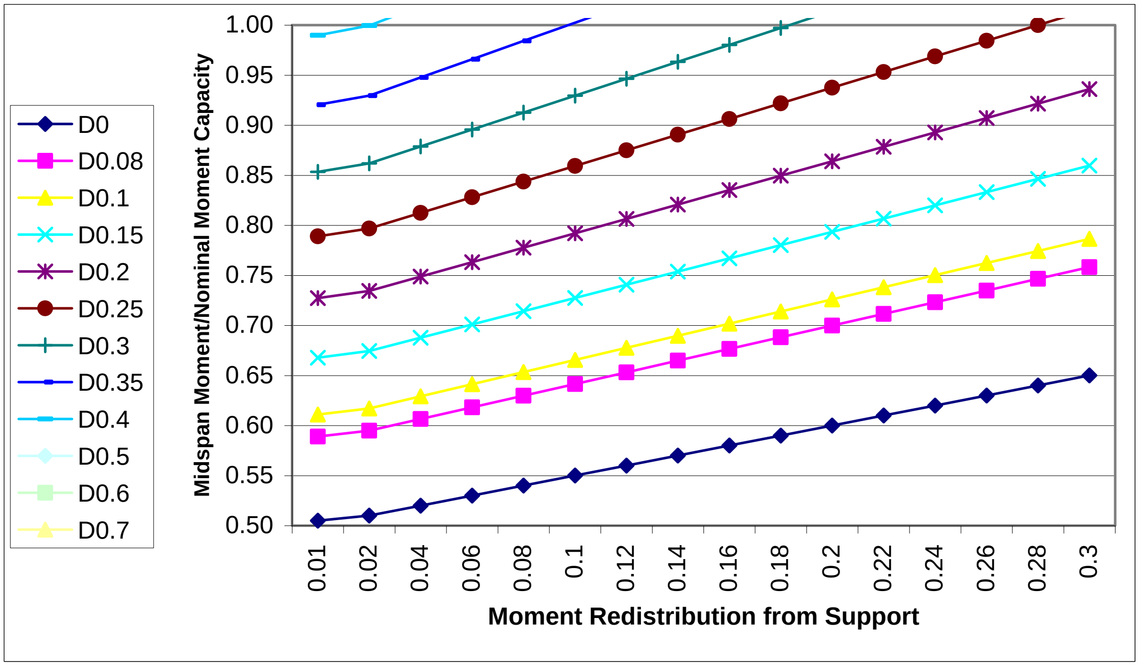


Fig. (10) Design Chart for one-end continuous span (Various *dL/L)*

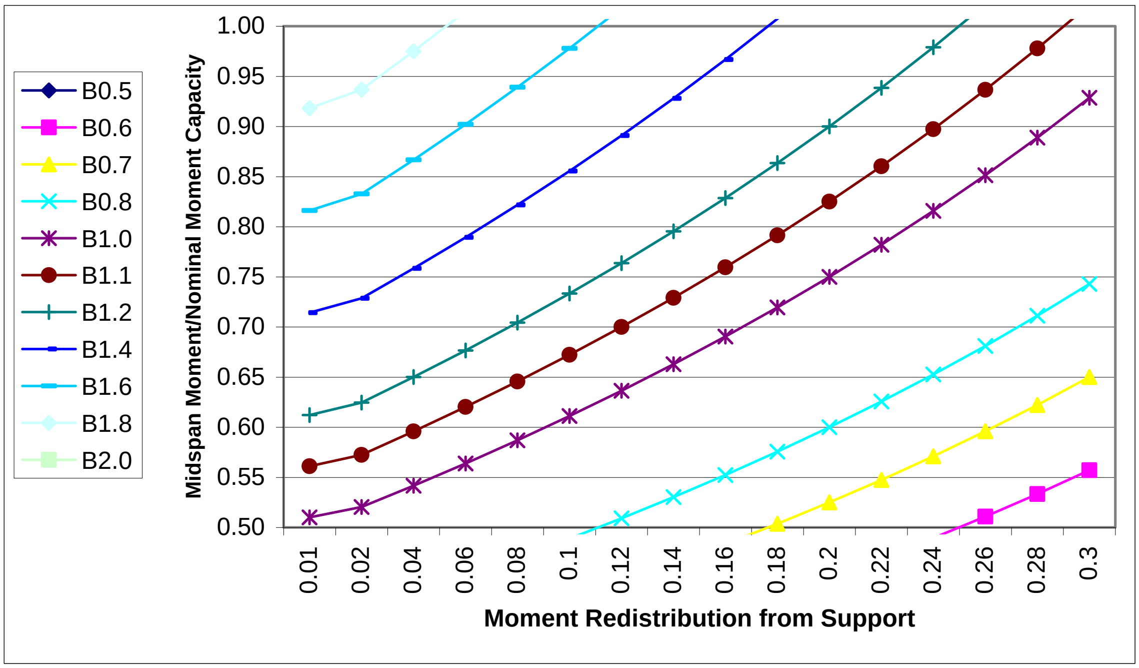


Fig. (11) Design Chart for one-end continuous span (Various β value*)*

The additional section should be checked for rotational capacity or ductility (as required for moment redistribution) in the usual manner. According to ACI [ACI-Committee 318, 2008], this is satisfied, respectively, by ensuring that the limit on the neutral axis depth at ultimate or the reinforcing index is not violated.

7. Span-Load Charts for Prestressed Concrete Hollow-Core Slab

A large number of computer runs using the finite element technique was made to produce curves that give a handy help for simple and fast design of prestressed hollow-core slabs under flexural service load. Curves are classified and presented considering the most common typical sections of the hollow-core slabs.

The function of the hollow-core member in practice is almost as either floor or roof, that limit the type of loading on be uniform distributed over the full span. On that base all loading obtained from these data are considered uniformly distributed.

7.1 Description of the chosen Hollow-Core Slabs

Figure (12) shows the over all section dimension. This slabs was tested numerically for different lengths starting from 3m span to 15m span. The support condition is fixed to the pin-roller case, and the loading considered is uniform distributed over the entire slab span. **Table (1)** gives the general section and material properties.

Table (1) Material properties.

Hollow-Core Slabs Design Details

120mm deep slabs

Sectional information

Cross section area =108,507 $10^3 mm^2$
Conc. 28 day strength =50N/ mm^2
Moment of inertia =161,752 $10^6 mm^4$
Conc. Strength at transfer =35N/ mm^2
Mod. Of Elasticity for conc. =34kN/ mm^2
Stressing of strand/ wire =70%
Centroidal axis from bottom =32,5mm

150mm deep slabs

Sectional information

Cross section area =124,674 $10^3 mm^2$
Conc. 28 day strength =50N/ mm^2
Moment of inertia =301,385 $10^6 mm^4$
Conc. Strength at transfer =35N/ mm^2
Mod. Of elasticity for conc.=34kN/ mm^2
Stressing of strand/ wire =70%
Centroidal axis from bottom =32,5mm

200mm deep slabs

Sectional information

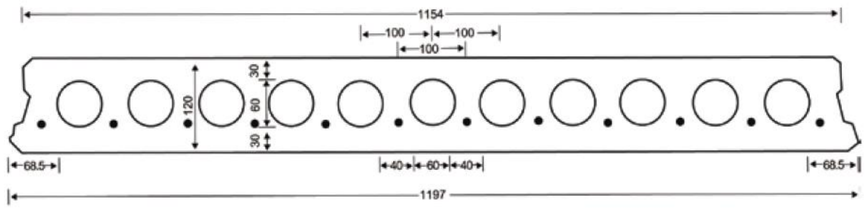
Cross section area =148,970 $10^3 mm^2$
Conc. 28 day strength =50N/ mm^2
Moment of inertia =661,627 $10^6 mm^4$
Conc. Strength at transfer =35N/ mm^2
Mod. Of elasticity for conc. =34kN/ mm^2
Stressing of strand/ wire =70%
Centroidal axis from bottom =32,5mm

250mm deep slabs

Sectional information

Cross section area= 174,855 $10^3 mm^2$
Conc. 28 day strength =50N/ mm^2
Moment of inertia =1205,857 $10^6 mm^4$
Conc. Strength at transfer =35N/ mm^2
Mod. Of elasticity for conc. =34kN/ mm^2
Stressing of strand/ wire =70%
Centroidal axis from bottom =34,5mm

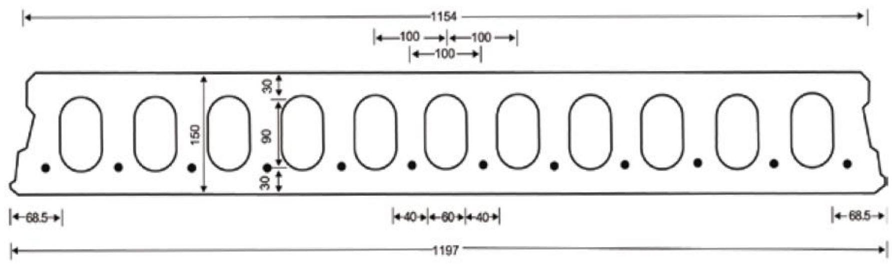
Cross Sectional Dimensions



A=8x5mm wires
B=12x5mm wires
C=9x5mm+3x9,53mm strand
D=7x5mm+5x9,53mm strand

Self Weight = 2.40kN/m²

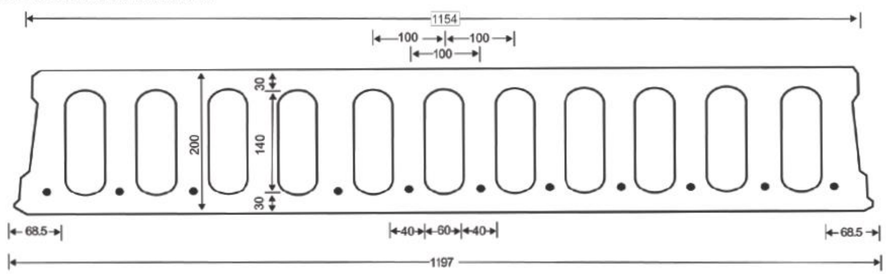
Cross Sectional Dimensions



A =8x5mm wires
B=12x5mm wires
C=9x5mm wires+3x9,53mm strand
D=7x5mm+5x9,53mm strand
E=4x5mm+8x9,53mm strand
F=12x9,3mm strand

Self Weight = 2.75kN/m²

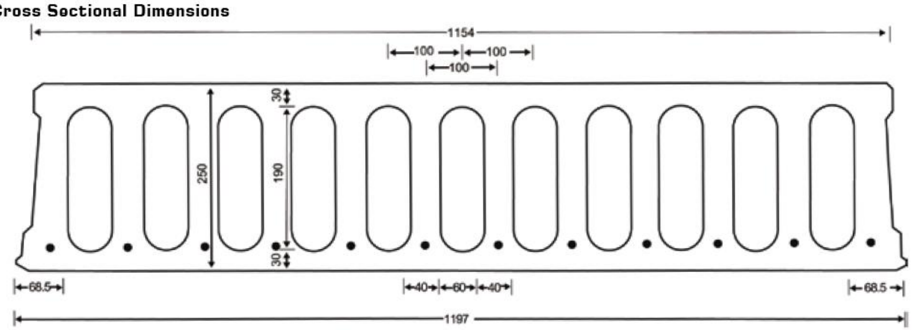
Cross Sectional Dimensions



A =8x 5mm wires
B=12x5mm wires
C=9x5mm wires+3x9,53mm strand
D=7x5mm wires+5x9,53mm strand
E =4x5mm + 8x9,53mm strand
F=12x9,53mm strand
K=4x5mm wires–top+8x9,53mm strand+4x12.5mm strand bottom

Self Weight = 3.29kN/m²

Cross Sectional Dimensions



G=10x9,53mm strand
H+2=9x9,53mm strand +3x12,5mm strand + 2x5mmwire-top
J+4=4x9,53mm strand + 8x12,5mm strand + 4x5mmwire-top

Self Weight = 3.86kN/m²

Fig. (12). Section dimensions (all dimension in mm).

7.2 Use of Hollow-Core Span-Load tables

Load Tables included herein were derived from computer-calculated data, are intended as aids to preliminary sizing, and must be interpreted using sound engineering judgment.

These Span-Load Tables present precast hollow-core slabs as indicated on the previous study, where the "standard" hollow-core slabs without composite topping is used which its commonly utilized for lightly loaded applications, such as roof structures.

Figures (13-20)shows the obtained moment capacity within the service and ultimate state, and overall load capacity, for the chosen section respectively., while the Figs. (21-24) shows the load-span design charts.

7.3 Design Criteria for development of the Span-Load Charts

The Span- Load Charts were developed as described below:

- **ALLOWABLE STRESSES** – The extreme fiber stress under full service load is limited to 0.45 $f_c^{'}$ for compression and $12\sqrt{f_c^{'}}$ for tension in accordance with ACI 318-05 for Class U or Class T prestressed concrete flexural members.
- **FLEXURAL STRENGTH** – The nominal flexural strength, ØMn, exceeds the required factored moment, Mu = 1.2Md + 1.6Ml , in accordance with ACI 318- 05, Sections 9.2.1 & 18.2.1. The strength reduction factor, φ, is calculated per Section 9.3.2.7. The stress in the pretensioned reinforcement at nominal strength (fps) is calculated in accordance with Sections 12.9 & 18.7.2, and all superimposed load is considered as live load. Where flexural strength governs the design, superimposed loads comprised of dead and live load combinations will increase the capacity over the values given in the Span- Load Charts.
- **SHEAR** – The nominal shear strength, ØVn, exceeds the required factored shear, Vu = 1.2Vd + 1.6Vl , in accordance with ACI 318- 05, Sections 9.2.1 and 11.1.1. Web shear strength (Vcw) is calculated in accordance with CTA Technical Bulletin 85B1. This method determines the applied shear which causes a principal tension of $4\sqrt{f_c^{'}}$ at the centroid of the pretensioned member, as allowed in ACI 318- 05, Section 11.4.3.2. Flexure shear strength (Vci) is calculated as set forth in CTA Technical Bulletin 78B1. This method uses a modified version of Equation (11- 10) of ACI 318- 05, based on full- scale testing of Hollow Core slabs.

  All values in the Span- Load Charts are based on Hollow Core slabs without shear reinforcement.
- **DEFLECTIONS** – Total deflection is defined as the upward camber of the slab due to the eccentricity of the pretensioning less the downward deflection due to applied loads, including the long- term effects of prestress loss, creep and shrinkage. Allowable loads from the Span- Load Charts limit the theoretical total deflection to *l*/180. In addition, the deflection due to prestress and dead load, including long- term effects, is limited to *l*/240. Instantaneous deflections due to live loads are limited to *l*/360. The load combinations considered in the deflection analysis are 50% dead and live load, or 100% live load.

Finite Element Analysis Results of 120mm deep hollow-core slabs

Moment Capacity kN/m	Wiring Patterns			
	A	B	C	D
Service moment	17.2	19.43	20.01	22.87
Ultimate moment	21.21	27.32	36.55	42.67

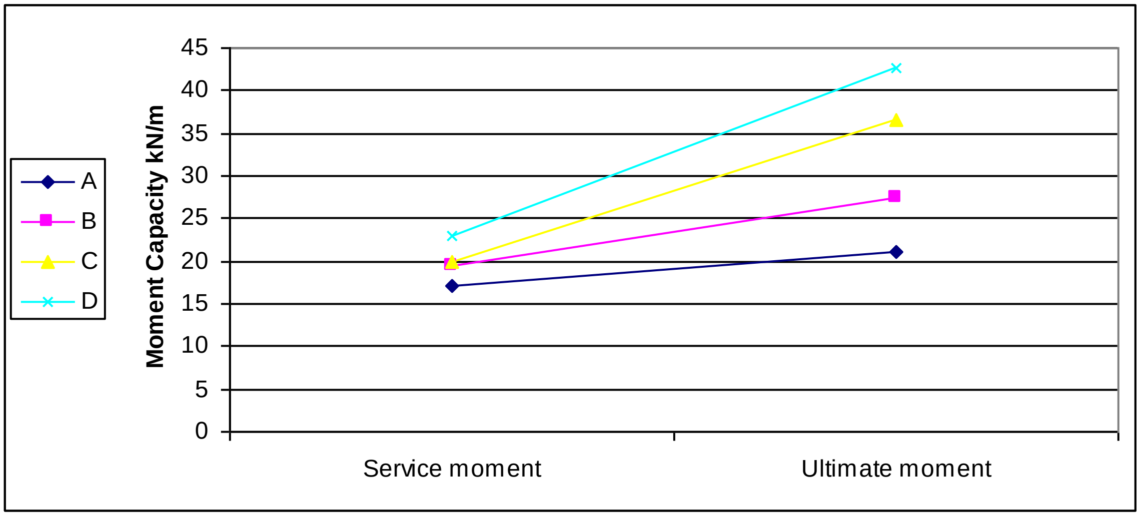


Fig. (13). Moment Capacity for 120mm deep hollow-core slabs within service & ultimate.

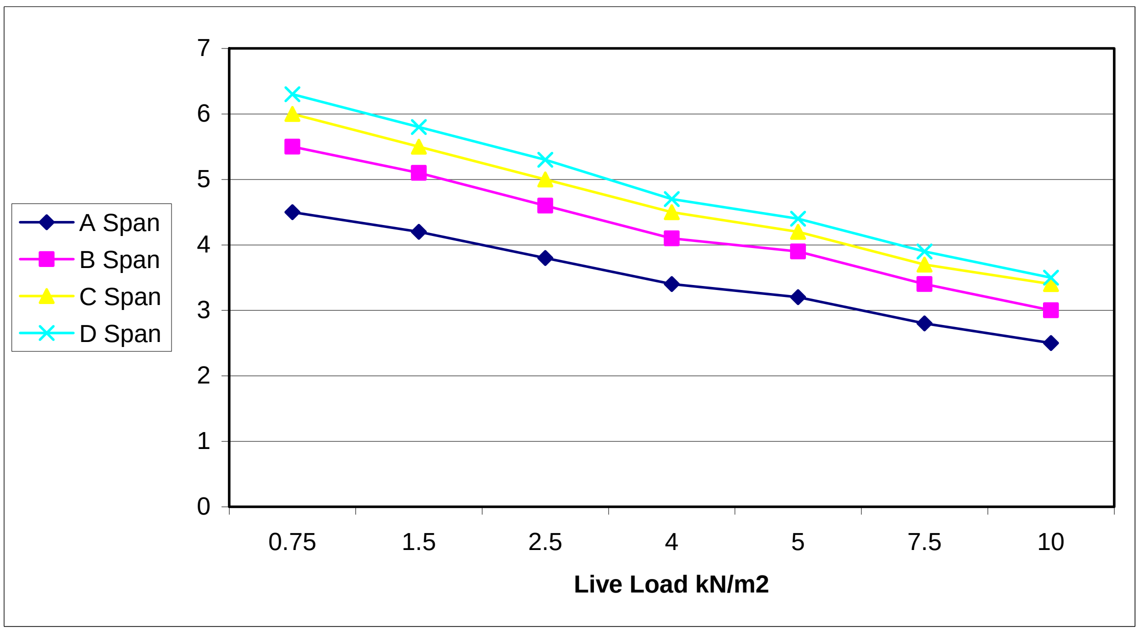


Fig . (14). Load Capacity outline for 120mm deep hollow-core slabs

Finite Element Analysis Results of 150mm deep hollow-core slabs

Moment Capacity kN/m	Wiring Patterns					
	A	B	C	D	E	F
Service moment	25.33	28.84	33.45	37.15	41.97	47.12
Ultimate moment	28.34	40.00	51.98	60.46	72.66	88.06

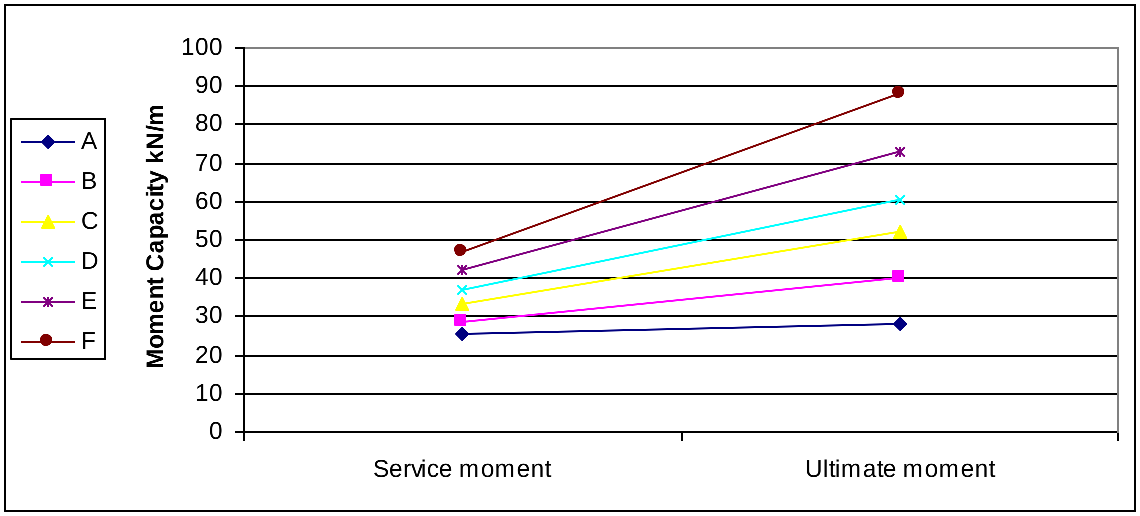


Fig. (15). Moment Capacity for 150mm deep hollow-core slabs within service & ultimate.

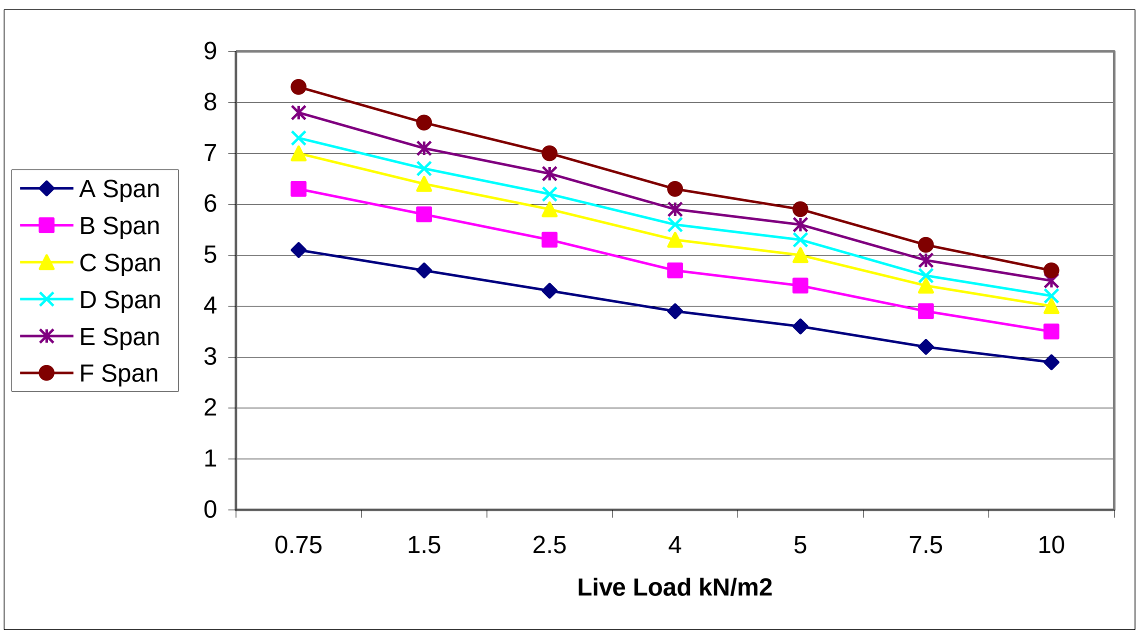


Fig . (16). Load Capacity outline for 150mm deep hollow-core slabs

Finite Element Analysis Results of 200mm deep hollow-core slabs

Moment Capacity kN/m	Wiring Patterns						
	A	B	C	D	E	F	K
Service moment	39.54	45.87	52.994	58.02	63.65	72.34	97.53
Ultimate moment	39.88	56.76	76.40	88.98	110.25	135.84	166.73

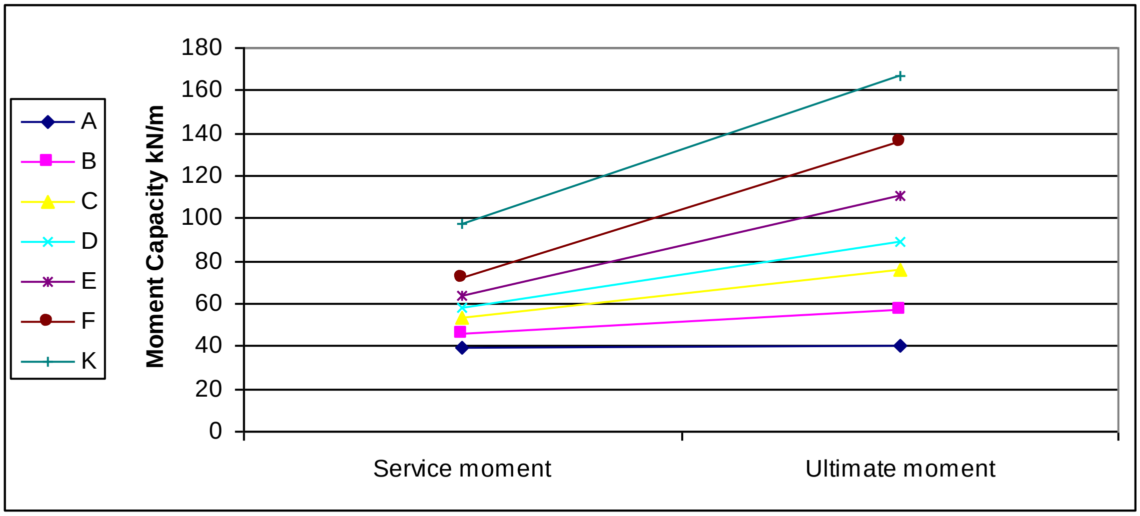


Fig. (17). Moment Capacity for 200mm deep hollow-core slabs within service & ultimate.

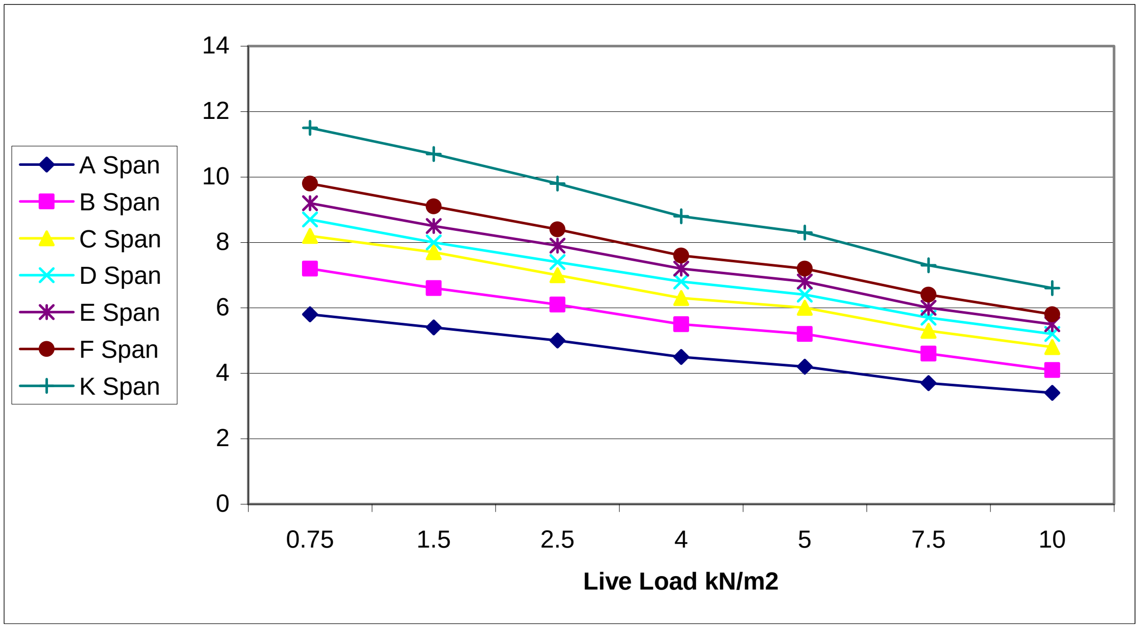


Fig . (18). Load Capacity outline for 200mm deep hollow-core slabs

Finite Element Analysis Results of 250mm deep hollow-core slabs

Moment Capacity kN/m	Wiring Patterns		
	G	H + 2	J + 4
Service moment	110.10	132.78	151.70
Ultimate moment	169.22	229.15	273.68

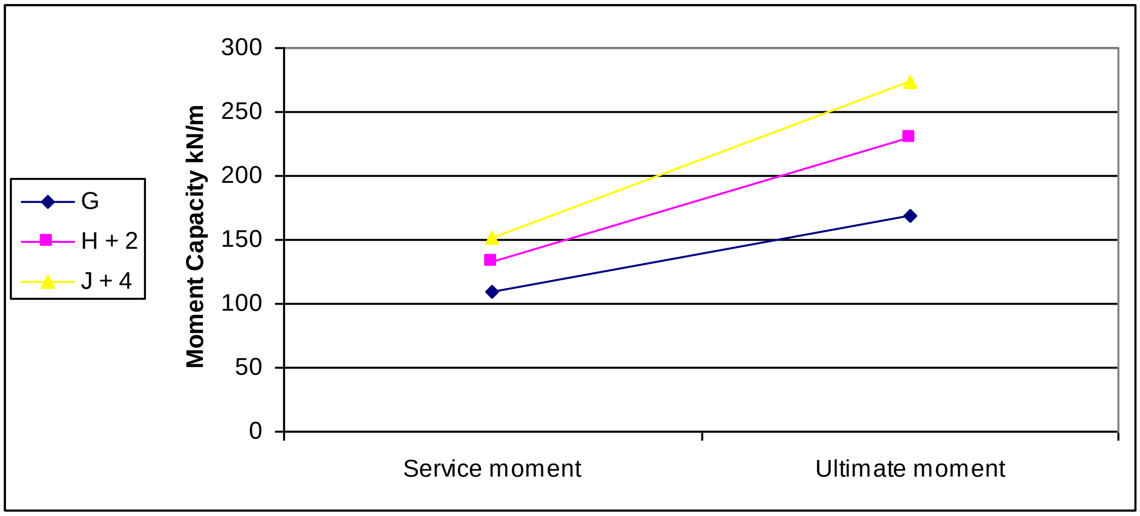


Fig. (19). Moment Capacity for 250mm deep hollow-core slabs within service & ultimate.

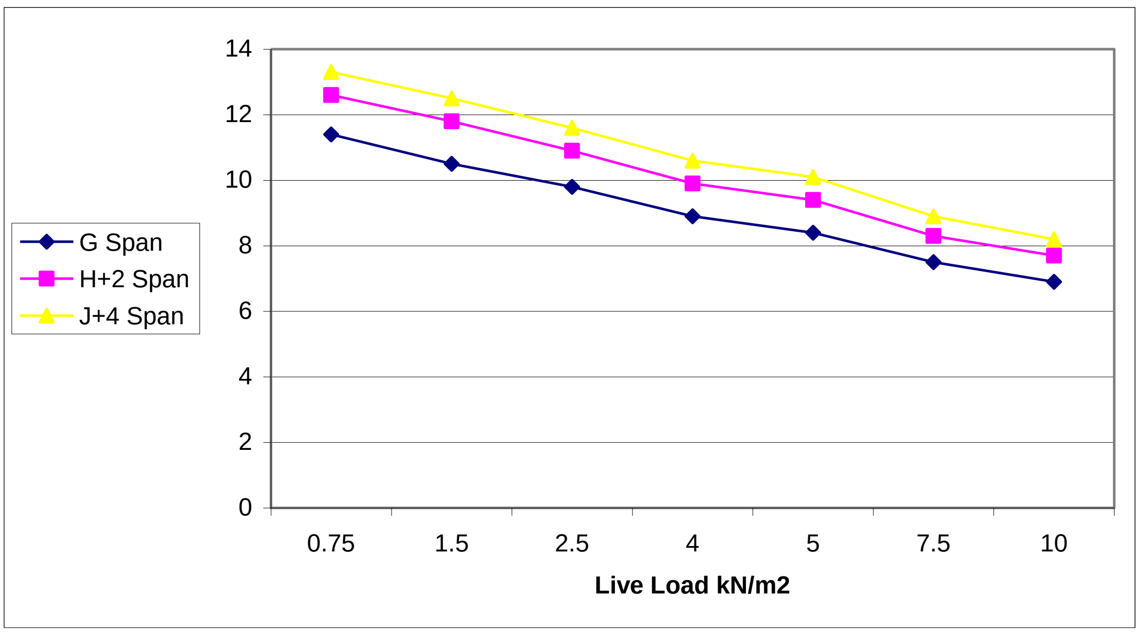


Fig . (20). Load Capacity outline for 250mm deep hollow-core slabs

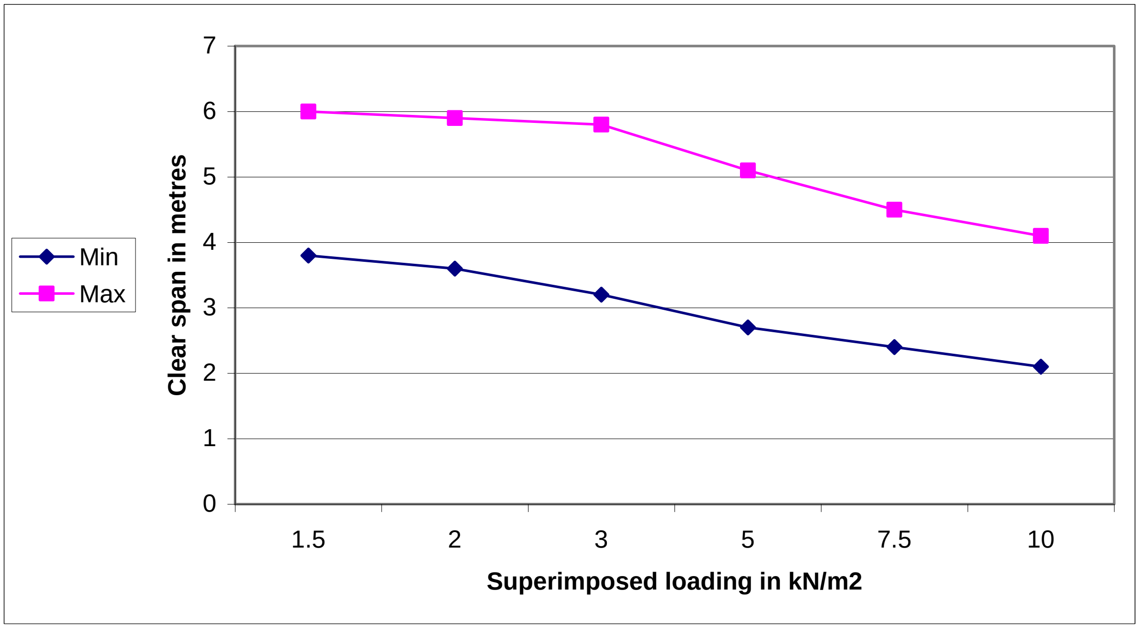


Fig. (21). Span-Load Charts for 120mm deep hollow-core slabs according to Min. & Max. Reinf.

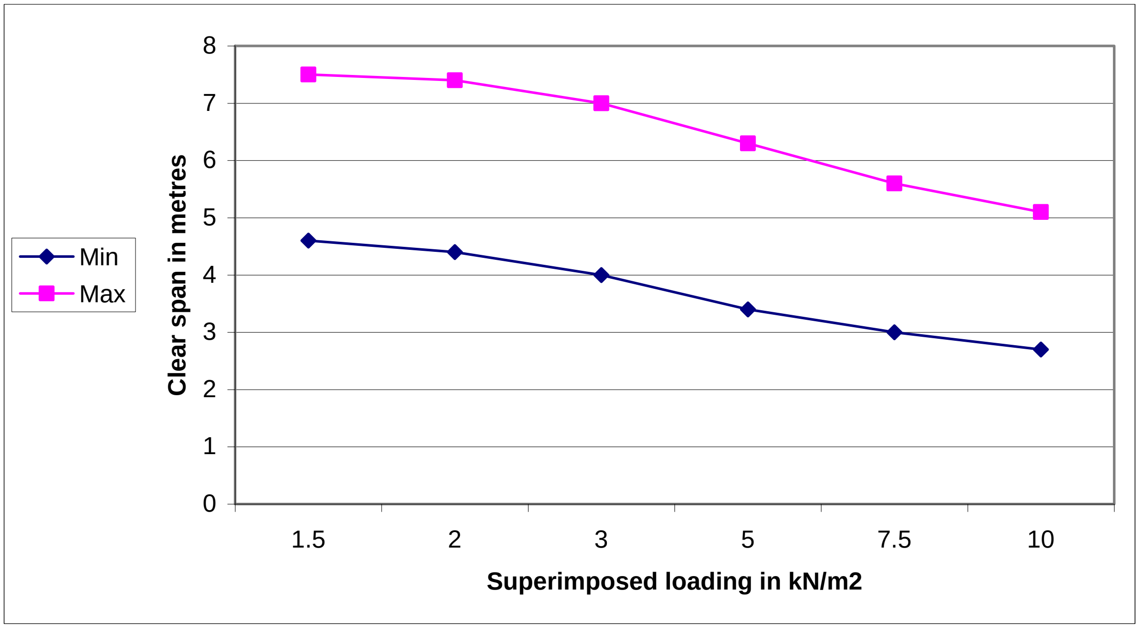


Fig. (22). Span-Load Charts for 150mm deep hollow-core slabs according to Min. & Max. Reinf.

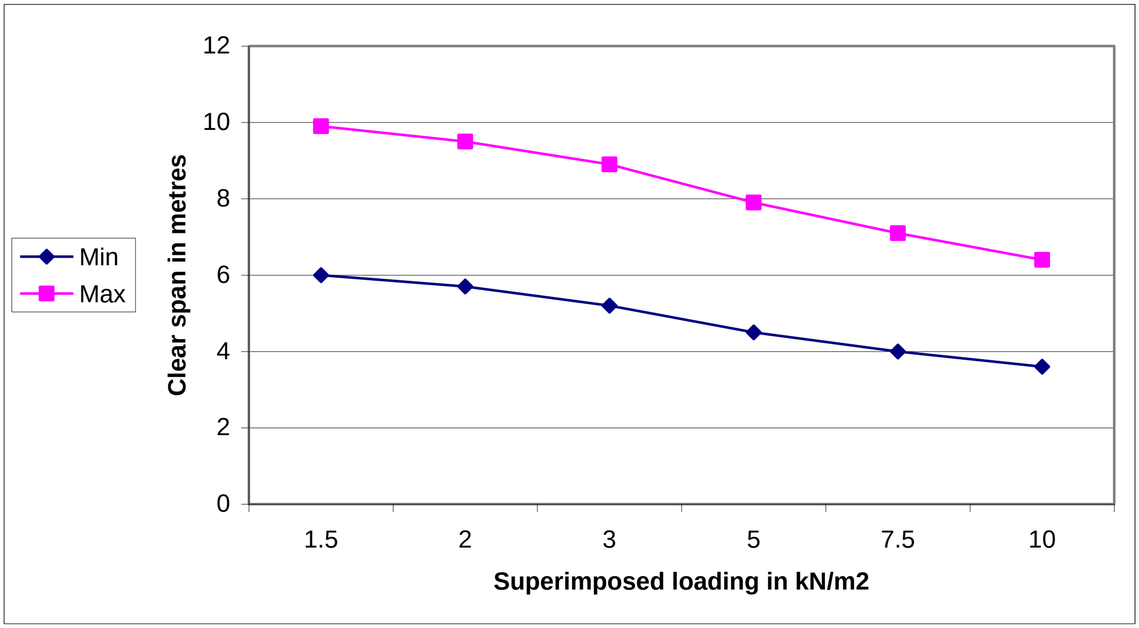


Fig. (23). Span-Load Charts for 200mm deep hollow-core slabs according to Min. & Max. Reinf.

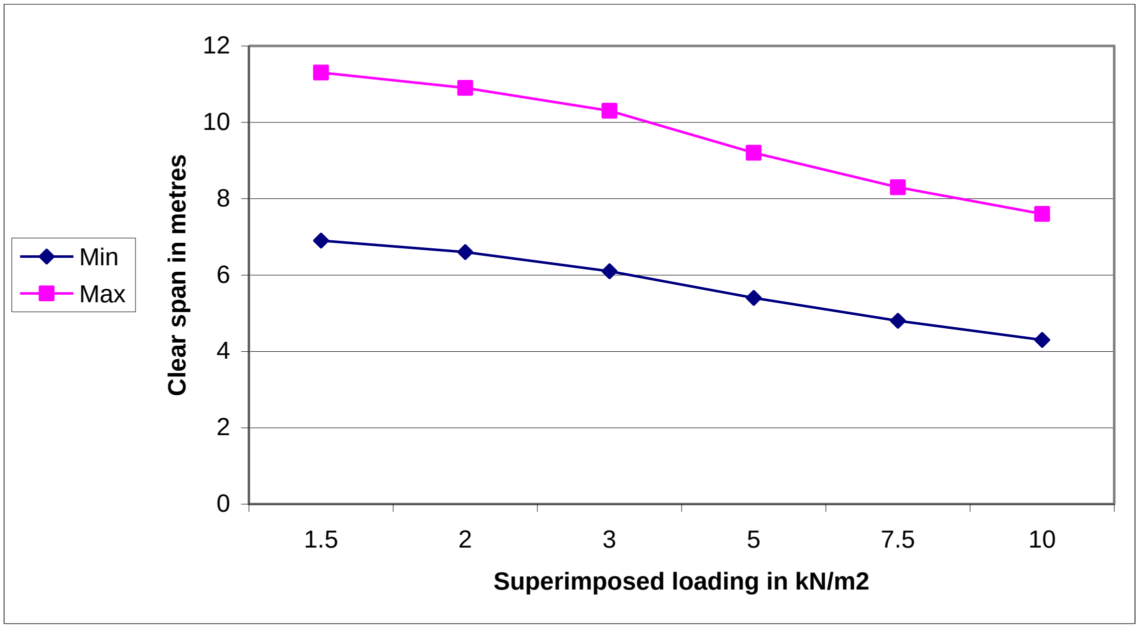


Fig. (24). Span-Load Charts for 250mm deep hollow-core slabs according to Min. & Max. Reinf.

8. Conclusions

1. In this study, charts for the design of one and two-end continuous hollow-core slabs were developed by the using of analysis and redesign by the finite element technique. These charts enable the required moment capacity at supports and the moment redistribution from supports to be determined for a desired increase in span capacity.
2. The three-dimensional finite element model used in the present work is able to simulate the behavior of ordinary and prestressed concrete hollow-core slabs under

flexure. The numerical tests carried out for the different cases studied showed ability of obtaining full behavior of the tested member under increasing load.

3. In the case of two-end continuous span, where α=1 and R≤0.3, the obtained span capacity of hollow-core slabs can be increased by between 37 and 70 percent. If the full positive moment capacity of slab is not used (that is, α<1), then the fractional increase in span capacity due to the provision of continuity at the supports would be correspondingly less.
4. In the case of one-end continuous span, where α=1 and R≤30 percent, the increase in span capacity varies from 24 percent to 41 percent.
5. The finite element techniques have been a suitable tool for large area analysis, as on creating the span-service load chart, where a large numbers of computer runs must be done. As a result; the charts could give a handy help for simple and fast design of ordinary and prestressed concrete hollow-core slabs under flexural service load.

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