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Conform- A Computerized Job-Built Concrete Construction Formwork Design

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CONFORM- A COMPUTERIZED JOB-BUILT CONCRETE CONSTRUCTION FORMWORK DESIGN

by

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Economy in formwork design depends partly on the ingenuity and experiences of the form designer, whether a contractor or an engineer. The cost of formwork is significant, generally amounting to anywhere from 40% to 60% of the cost of a concrete structure. Judgment with respect to the development of a forming system could both expedite a project and reduce costs. The present paper addresses the development of *CONFORM* - an interactive menu driven PC based job-built concrete formwork design. The system is developed using Microsoft Visual Basic 6, Access 97 database, and Word 97, where a perfect integration of these Windows applications has been made to get a true WYSIWYG (What You See Is What You Get) environment. The calculation process consists of "event driven activities" which lets the users to trail-and- error their data input, and redesign as if the results are not satisfactory. The final results including formwork drawing with material sizes and spacings can be seen on the screen, and be saved in word documents or text formats. The *CONFORM* can have ideal use both at the job site as well as at the engineer's office, and will save significantly the formwork design time.

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L = span length (center to center of supports) (in.)

Fb = allowable bending stress (psi)

S = section modulus ($in.^3$)

W = uniform load (lb/ft)

F = allowable shear stress (psi)

A = cross-sectional area ($in.^2$)

D = depth of member (in.)

E = modulus of elasticity (psi)

I = moment of initial (in.)

Ib/Q = rolling shear constant for plywood (in)

Cd = load duration factor

Cm = wet service factor

Ct = temperature factor

Cf = size factor (not applicable to southern pine)

Cfu = flat use factor

Cr = repetitive member factor

CL = beam stability factor

Cp = column stability factor

Ch = shear stress factor

CHAPTER I

INTRODUCTION

Forms are temporary structures whose purposes are to provide containment for the fresh concrete and to support both the pressure of wet concrete and all temporary construction loads, including lateral loads, until the concrete reaches a strength level at which it becomes self-supporting. A well-designed form must have adequate strength to resist failure and in addition must have sufficient stiffness so that deflection will not be excessive. The cost of formwork is significant, generally amounting to anywhere from 40% to 60% of the cost of a concrete structure. Economy in formwork design depends partly on the ingenuity and experiences of the form designer, whether a contractor or an engineer. Judgment with respect to the development of a forming system could both expedite a project and reduce costs. Efficient and economical use of the material of which the forms are built is an integral part of the design process.

Most commonly used material for job-built forms for concrete structures include timber, plywood, and hardboard. Additional materials include nails, bolts, screws, form ties, form clamps, anchors, and various other inserts. Form timber generally consists of the softwoods with the species that available in the local area. In multiple reuse situations, steel formwork has replaced wood formwork to some degree, although the use of timber is still substantial because of its availability and ease of fabrication. Timber differs in several significant ways from other construction materials (such as steel, plastic), mainly because of its cellular structure. Because of the cellular structure, the strength of form depends on wood orientation. Although most structural materials are essentially isotropic, with nearly equal properties in all directions, timber has three principal grain directions: longitudinal, radial, and tangential. Loading in the longitudinal direction is referred to as parallel to the grain, whereas transverse loading is considered across the grain. Parallel to the grain, timber possesses high strength and stiffness, whereas across the grain, strength is much lower. Furthermore, a timber member has three modulus of elasticity, with a ratio of largest to smallest as large as 150:1. Because of allowable stresses depend on so many factors including the species of wood, grade, cross-section, moisture content, and load duration, it is impossible to recommend a single set of working stresses for formwork design. Moreover, these base stress values must be adjusted by several adjustment factors that relate to their conditions of uses. This makes the formwork design computations much more complex and time consuming compare to steel formwork design.

This research presents a PC based formwork design tool, *CONFORM*, which can be ideally used both at the job site as well as at the engineer's office. This interactive design tool will save significantly the formwork design time.

CHAPTER II

OBJECTIVES AND SCOPE OF THE PROJECT

Objective of the Project

The main objective of this project is to develop a PC based job-built concrete construction formwork design tool, *CONFORM*, by integrating Windows applications- Microsoft Visual Basic 6, Access 97 and Word 97. In this project, a PC based formwork design tool, *CONFORM*, is developed, which can be ideally used both at the job site as well as at the engineer's office. This interactive design tool can save significantly the formwork design time.

Scope of the Project

The program has four main design modules, which are (1) Slab Formwork Design, (2) Column Formwork Design, (3) Beam Formwork Design, and (4) Wall Formwork Design. The program designs the wooden formwork system only. The use of wood in forming formwork is widely accepted as it provides the ease of use in many situations. Wood can be formed as many dimensions, as the concrete structure will be because wood is a very bendable material. Wood also has good strength-to-weight ratio, workability, and cost efficiency. Spruce, pine, fir and western hemlock are the species most commonly used in concrete formwork materials.

The entire design processes consist of "event driven activities " that requires the interaction between the user and the program. The formwork sketch drawings can be seen at any time on the screen by clicking at the "Help Picture" button, which explain the definitions of various members and their interrelationships regarding load transfer mechanism. The system provides a point-and-click environment, so the user does not have to find the application program to open the design data files (Access tables); the files are automatically launched into the correct application for calculations. The integration of Windows applications enable the *CONFORM* users to concentrate on working with the design data instead of with a variety of applications. The Access tables containing material properties, section properties, allowable design values and design value adjustment factors can be updated independently without going through the main program. The calculation processes let the user to trail-and-error their entering data, design criteria, and redesign as if the results are not satisfactory. The final results include formwork sketch drawing with material sizes and spacing, and can be saved in word documents or text formats.

The *CONFORM* have ideal use both at the job site as well as at the engineer's office, and save significantly the formwork design time. At the job site, *CONFORM* can be run in a Lap-top PC, and by entering the input data based on available sizes of timbers and plywood/plyform formwork construction specifications (member sizes, spacings, etc.) including drawings can be produced both at the PC screen as well as hard copy. These features will certainly enhance the construction process by proper and timely utilization of available form construction materials on the job site.

CHAPTER III

FORMWORK DESIGN LOADS

Vertical Loads

Dead load includes slab weight and formwork weight (about 10% of the slab weight). The dead load is assumed to be uniformly distributed during construction. Live load includes workmen, equipment, material storage, the effect of non-uniform loading during concrete placement, impact effect of concrete bucket dropping, buggy moving, and so on.

ACI Committee 347 (ACI 347R-94) recommends a minimum construction live load of 2.4 kPa (50 psf) for workmen, equipment, runways, and impact, and 3.6 kPa (75 psf) when using motorized carts for transporting fresh concrete. The minimum design load for combined dead and live loads should be 4.8 kPa (100 psf), or 6.0 kPa (125 psf) if motorized carts are used.

Lateral Pressure of Fresh Concrete

ACI Committee 347 (ACI 347R-94) recommends for concrete made with Type I cement, weighing 2400 kg/sq.m (150 pcf), containing no pozzolan or admixture, having a slump of 10.2 cm (4 in) or less and normal internal vibration to a depth of 1.22 m (4 ft) or less, formwork may be designed for lateral pressure, p

calculated by using the following non-homogenous equations, where R = rate of concrete placement, m/hr (ft/hr); and T = temperature of concrete in the form.

Using Imperial Units

For a "h" ft high wall with rate of concrete placement less than 7 ft/hr. will use $p = 150 + 9000\ R/T$ with a maximum of 2000 psf, a minimum of 600 psf, but in no case greater than $150h$.

For a "h" ft high wall with rate of concrete placement from 7 to 10 ft/hr. will use $p = 150 + 43{,}400/T + 2{,}800\ R/T$ with a maximum of 2000 psf, a minimum of 600 psf, but in no case greater than $150h$.

For a "h" ft high column, where lifts do not exceed 18 ft. will use $p = 150 + 9000\ R/T$, with a maximum of 3000 psf, a minimum of 600 psf, but in no case greater than $150h$.

Using SI Units

Walls: For a "h" m high wall with rate of concrete placement less than 2 m/hr will use $p = 7.2 + 785\ R/(T+17.8)$, with a maximum of 95.8 kPa or $23.5h$ kPa, which ever is least. For a "h" m high wall with rate of concrete placement from 2 to 3 m/hr. will use $p = 7.2 + 1{,}156/(T+17.8) + 244\ R/(T+17.8)$, with a maximum of 95.8 kPa or $23.5h$ kPa, whichever is least.

For a "h" m high column will use $p = 7.2 + 785\ R/(T+17.8)$, with a maximum of 144 kPa or $23.5h$ kPa, whichever is least.

Horizontal Loads

Braces and shores should be designed to resist all foreseeable horizontal loads such as seismic forces, wind, cable tensions, inclined supports, dumping of concrete, and starting and stopping of equipment. Wind loads on enclosures or other windbreaks attached to the formwork should be considered. ACI Committee 347 (ACI 347R-94) recommends the horizontal loads to be either 1.5 kN/m (100 lb/ft) or 2% of the total superimposed dead load, whichever is greater. Both ACI 347R-94 and ANSI Standard A58.1 requires a minimum wind load of 0.72 kPa (15 psf). Wall form bracing should be designed to meet the minimum wind load requirements or of the local building code, whichever is more stringent. Bracings for wall forms should be designed for a horizontal load of at least 1.5 kN/m (100 lb/ft) of wall, applied at the top.

CHAPTER IV

JOB-BUILT FORMWORK CONSTRUCTION MATERIALS

Basic Materials for Formwork

Materials that are used to build formwork structures are including with lumber, plywood, hardboard, fiberglass, plastic, rubber liners, steel, paper, cardboard, aluminum, and fiber forms. Each of those materials requires different design process. However, formworks generally involve the use of two or more materials together such as using plywood for sheathing system while using steel frames for shoring system. In this software, the program uses only softwoods as formwork materials to simplify the design processes.

Most commonly used job-built concrete formwork materials include timber, plywood, and hardboard. Additional materials include nails, bolts, screws, form ties, form clamps, anchors, and various other inserts. Formwork timber generally consists of the softwoods with the species available in the local area. Some of the most commonly used timbers for concrete formwork are (a) Douglas fir-larch (Douglas fir, western larch); (b) Douglas fir-South (only Douglas fir from southern growth areas); (c) Hem-fir (Western hemlock, California red fir, grand fir, noble fir, white fir, Pacific silver fir); (d) Spruce-pine-fir (alpine fir, balsam fir, black spruce, Englemann spruce, jack pine, lodgepole pine, red spruce, white spruce); (e) Southern pine (loblolly pine, longleaf pine, shortleaf pine, slash pine).

Plywood which is available as flat panels (1.2 m x 2.44 m / 4 ft x 8 ft) are made of thin sheets of wood (called plies) with a total thickness ranging from 0.64 to 2.86 cm (0.25 to 1.125 in). It is commonly used for sheathing or lining forms because it gives smooth concrete surfaces. For maximum strength, the direction of the grain should be placed parallel to the span. With proper care, plywood can be reused many times. Plyform is exterior-type of plywood limited to certain wood species and veneer grades to ensure high performance, and is manufactured in two classes, *class I* and *class II*. *Class I* is the strongest, stiffest, and most widely available type. However, both classes have smooth and rigid surfaces and can have many reuses. Plyform is manufactured in thickness ranging from 1.19 to 2.86 cm (0.469 to 1.125 in), and the most commonly used thickness are 1.59 cm (0.625 in) and 1.90 cm (0.75 in). Plyform can also be manufactured with a high-density overlaid (HDO) surface (on one side or both sides). This can have as many as 200 reuses.

Hardboard (fiberboard) is made up of wood particles that have been impregnated, pressed, and baked. Hardboard has limited reuse capability.

Wood formworks are built from standard sizes, which can be called as rough size or dressed size. In the design processes, designers usually refer the lumber size as dressed size. Shoring elements are required to be more square shaping then stringer or joint elements. Those lumber species have been proved that they have are durable enough to prevent unpredictable crack, excessively swell, and erosion. Wood boards may be used for sheathing when the designers want to design the concrete surface for architectural reasons.

Formwork Accessories

Designs of formwork accessories are not included in this designing software. However, details of form accessories can be found from manufacturers' catalogs as well as local concrete construction distributors. The designs of formwork accessories are mostly identified by worker experiences or rule of thumbs.

The accessories consist of many items that are necessary to build formworks. Some of the more common types of accessories are as follows. Fasteners are performed by using the double-headed nail, which may be withdrawn with a minimum of effort and lit-tie damage to the formworks. Spearders are braces that are inserted in formworks to keep the faces a proper distance until the concrete is placed. Spearders should be removed after the placement of the concrete so that they are not cast in the concrete. Ties are used to holding concrete formworks against the lateral pressure of the fresh concrete. Ties should have highly tensile strength for holding formworks. Anchors normally are used to embed in concrete during placement. There are two basic parts, the embedded anchoring device and the external fastener, which is removed after use. Hangers are devices used for suspending one object from another, such as the hardware attached to a building frame to support forms._Inserts are attached to the forms in such a way that they remain in the concrete when the forms are stripped. They provide for anchorage of brick or stone veneers, pipe hangers, suspended ceilings, duct works, and any building hardware or components that must be attached to the concrete. Clamps consist of many varied devices, but serve a similar purpose to that of the tie. Beam form clamps firmly hold the beam sides and bottom together with a minimum of nailing required. Column clamps or yokes encircle

Wood Section Properties

The section properties, allowable design values (allowable base stress value, modulus of elasticity etc.) of the above form construction materials, and applicable design value adjustment factors are available in various literatures including American Plywood Association's publication -Plywood Design Specifications (1995), and Concrete Forming (1994), and many timber design handbooks and publications (ANSI/NFoPA NDS 1991, Faherty, F. K., and Williamson, G.T.1995, Hurd, M.K. 1995, Spiegel, L., and Limbrunner, G.1998).

In this computer based formwork design, there are 4 tables that identify the properties of wood that can be selected by the users: (1) Plyform property table, (2) Lumber property table, (3) Design value table, and (4) Cu and Cfu factor table.

The "plyform" design values are based on wet strength and 7 days load duration, so no further adjustment in these values is required except for the modulus of elasticity. The modulus shown is an adjusted value based on the assumption that shear deflection is computed separately from bending deflection.

CHAPTER V

PRINCIPLES OF CONCRETE FORMWORK DESIGNS

Basic Requirements for Designing Forms

One purpose of using computer based formwork design is to design formworks that will meet the essential requirements of structural engineering and construction engineering. The quality requirements of formworks are based on the quality requirements of permanent structures. Formworks must be able to support all loads that are occurred during the construction times. The design of formworks had been stated in the standard regulation code as well as permanent structures.

The following section describes the typical requirement for formwork that may be categorized as (a) quality requirements, (b) safety requirements, and (c) economy requirements.

Quality Requirements

The size, shape, position, and alignment of concrete structural elements will directly depend on the accuracy of formworks. The designer should concern about the defections allowable in formwork elements for form design and construction, but they should not build or design the deflection allowable more finesse than necessary because this could add unnecessary cost as well as delay the project. Moreover, the position of formwork respected to the position of final concrete structure must be determined.

Forms must have sufficient rigidity that in order to prevent movement during the placing of concrete. Formwork must therefore be significantly propped, braced and tied. Joints that are insufficiently tight will leak cement paste. Formworks must be tighten enough to prevent the leak of fresh concrete as well as to prevent the distortion of concrete structure. Formwork should be made to fit.

The formwork surface that will contact with concrete should be taken care as to produce a good bound of concrete surface and good final surface appearance. In this case, the use of plywood or plyform might be the best approach since those can provide reasonably good surface. The surface maintenance by the user is again out of concern in this program software.

Safety Requirements

Formwork must be designed to carry the full load and side pressures from freshly placed concrete, construction traffic (workers and their movements), and any necessary equipment. In the large construction jobs, a specialist usually designs formwork. In the smaller or routine jobs, it may be designed by the carpenter supervisor or by using rule-of-thumb. Both of those cases, this computer based formwork design can help them to design forms. Formwork materials must be built by the correct size of wood and have sufficiently durable for the job.

For formwork construction to be economical, it must be designed to be simple to be built and reused. The material used should be easily found near site or not too expensive to buy. The sizes of form panels or units should be such that they are not too heavy to handle. Comparative ease of assembly and the possibility of reuse will lower formwork costs when sizes are standardized. Formwork intended for reuse should be designed for easy removal. If formwork panels have to be ripped down, the concrete may be damaged, materials will be wasted, time will be lost, and expense will be incurred in repairing and replacing damaged panels

This issue is directly involved in using this program package. The designer can check their design whether the design is well enough or the design is over estimated.

After we know some requirements of good formwork, the following articles will describe more about the basic permanent structural design that must be applied to formwork design. Not to mention that the design approach must be based on the requirements that the article just described.

Design Methods

The design of job-built forms may be considered largely as beam and post design. The bending members usually span several supports and therefore indeterminate. Assumptions and approximations are made that simplify the calculations and facilitate the design process (Hurd, M.K. 1995, Spiegel, L., and Limbrunner, G.1998). After establishing the appropriate design loads, the sheathing and supporting members are analyzed or designed in sequence. Bending members (sheathing, joists, studs, stringers, or wales) are considered to be uniformly loaded and supported on a (1) single span, (2) two spans, or (3) three or more spans. The uniform load assumption is common practice unless the spacing of point loads exceeds one-third to one-half of the span between supports, in which case the worst loading conditions is investigated. Wood forms are designed by working stress methods recommended by the American Forest and Paper Association. Detailed analysis and design of formwork for slabs, beams, columns and walls are available in various literatures (Hurd, M.K. 1995, Spiegel, L., and Limbrunner, G.1998).

The first step in the designing form is that to simplicity the design processes. The design of job-built forms may be considered on beam and shore design. The bending members usually span several supports and are therefore considered as continuous spans.

Designer must establishes the appropriate design loads that can be applied to the formwork members. The sheathing and other members are analyzed or designed.

Normally bending members (sheathing, joists, studs, stingers, or wales) are considered to be uniformly loaded and supported on (1) a single span, (2) two spans, or (3) three or more spans. To simplify the design tasks, the program will assume the design beam as continuous span for safety design. The uniform load assumption is also assumed, unless the spacing of point loads exceeds one-third to one-half of the span between supports that will create extra shear stress. In case of point loads are assumed, the designer must recalculate the final result with care.

Generally, each bending member should be analyzed or designed for (a) bending moment, (b) shear, (c) deflection, and (d) bearing stress. Especially in the shoring design, vertical supports (shoring) and lateral bracing (if needed) must be analyzed or designed for either compressive or tensile stress. In the analysis or design of the component parts the traditional stress equations are used (see any strength of materials text.

Usually formwork designers assume the maximum unit stresses or loads into a uniformly distributed load **w** (lb/ft), that will gives the maximum allowable span length. Therefore, knowing the design loads and member section properties, a maximum allowable span length can be computed.

Different type of structure span has different maximum allowable span length. There are three types of span, which are single span, double span, and continuous span.

The moment expressions are based on the maximum positive or negative moment. The maximum shear is existed at **d** distance from the support, where **d** is the depth of the member.

Adjustment Factors

The products of the design value ($\mathbf{F_b}$ for moment or $\mathbf{F_v}$ for shear) and other applicable adjustment factors provide an allowable unit stress in the design and analysis of wood members. The allowable unit stress is denoted as a primed value (e.g., $\mathbf{F_b'}$), which indicates that it is an adjusted design value calculated for specific conditions, For instance, for allowable shear stress use the following formula: $Fv' = Fv * Cd * Cm * Ct * Ch$.

If no adjustment factor is applied, then the allowable unit stress will be equal to the tabulated base design value (e.g., $\mathbf{F_b'}$). One required value that is not an allowable stress is modulus of elasticity E. It will be determined in a similar fashion as the product of design values and applicable adjustment factors.

Determination of Allowable Bending Stress

The wet service factor **Cm** is applicable when the moisture content of the wood is more than 19% (which would occur in a wet service situation such as when the wood is in contact with fresh concrete) and the wood is at ordinary temperature.

The temperature factor **Ct** is generally not applicable in form design and may be disregarded. Applicable adjustment factors for allowable shear stress are wet service, load duration, temperature, and shear stress.

The wet service factor $\mathbf{C_m}$ and the load duration factor $\mathbf{C_d}$ are furnished in the previous table. The temperature factor is generally not applicable in form design.

The shear stress factor $\mathbf{C_h}$ is a function of wood imperfection. Conservative practice suggests that $\mathbf{C_h}$ =1.0 be used whenever there is no information on splits, checks, and shakes for the lumber in question. For the examples and problems of this chapter, the value of $\mathbf{C_h}$ will be taken as 1.0.

Applicable adjustment factors for allowable stress perpendicular to the grain are wet service, temperature, and bearing area. Note that the stress increase for short-term loading does not apply to $\mathbf{F_{ct}}$

The wet service factor $\mathbf{C_M}$ is the temperature factor is generally not applicable in form design.

The bearing area factor $\mathbf{C_b}$ is applicable where the bearing length is less than 6 in. long and at least 3 in. from the end of the member. It may be calculated from $Cb = (Lb+0.37)/Lb$ where $\mathbf{L_b}$ is the length of the bearing (in.) measured parallel to the bearing. For bearing at the end of a member and lengths of bearing equal to 6 in. or more, use $\mathbf{C_b}$ = 1.0. Note that $\mathbf{C_b}$ will never be less than 1.0. Therefore, it is conservative to omit it. The only applicable adjustment factor for modulus of elasticity in form design is the wet service C_M (E' = E * Cm).

CHAPTER VI

PROGRAM ARCHITECTURE AND DEVELOPMENT METHODOLOGY

Software Development Methodology

In today's fast-changing world, program maintenance is more critical than ever before. Companies change, industries consolidate, spin-offs happen. The computer programs of today must be fluid and maintainable so that programmer can quickly change the program to meet the needs of a changing environment in which the programs are used. The program uses Microsoft Access 97 database, Word 97, and Microsoft Visual Basic 6 for the development of this system. Access is a database program of the Microsoft Office Professional that is quickly becomes a leader in the industry because of its powerful capabilities and ease of use. Visual Basic is an enjoyable language due to its visual environment which is one of the first programming languages to incorporate a true WYSIWYG (What You See Is What You Get) environment. The *CONFORM* offers a high degree of user interaction using the graphical elements that form the objects on the window the user sees.

Software Architecture

The architecture of *CONFORM* is shown in Figure 1, where a powerful integration of three Microsoft Windows applications - (1) Visual Basic 6, (2) Access

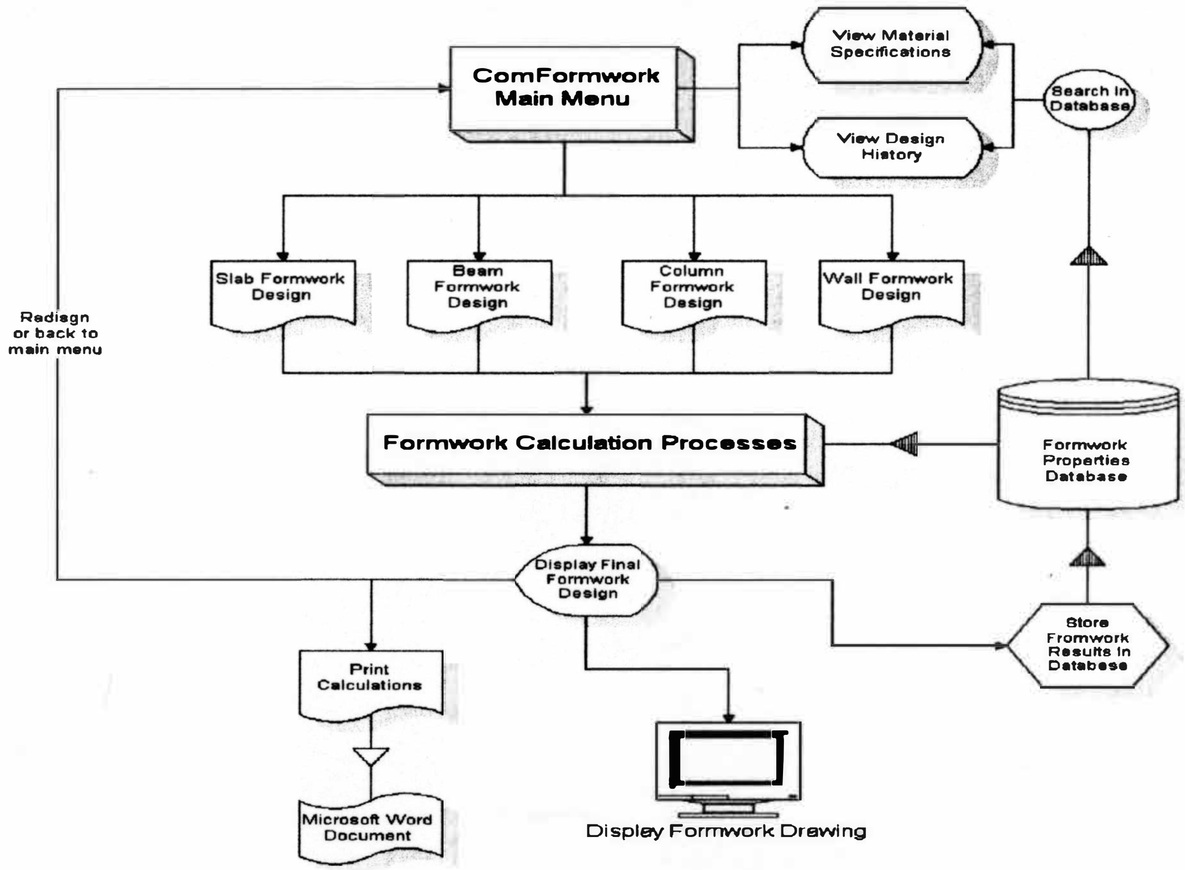


Figure 1. Architecture of *CONFORM*.

97, and (3) Work 97 has been done. The program uses Visual Basic 6 as the main programming language for calculation, Access 97 database for storage of material properties, section properties, allowable design values and all applicable design value adjustment factors, and both the Access 97 and Word 97 for input and output data storage and design report generation. In the database, there are five tables in Figure 2 which are (1) Plyform property table, (2) Lumber property table, (3) Design value table, (4) Size factor (C_f) and Flat use factor (C_{fu}) table, and (5) Size factor for compression parallel to grain, Special C_f factor table. These data are linked to the main Visual Basic program module by using data control techniques. The CONFORM provides the ease of use in term of material selections and material properties identifications. The user will be required to enter basic design criteria such as normal size of wood or concrete structure size, then the program will use those basic criteria to identify the other criteria in the database. As most of technical criteria such as bending stress of each wood grade is not familiar and convenient to be entered manually. The basic calculations such as area of wood section and dressing size of wood are also primary recorded in the database for ease of use.

The database system in computer based formwork design consists of four tables. The design tables provide the technical factors, property factor, and other factors those are needed to complete the calculation problem. The user will get the technical factors by the search system that link the enter value with the database. Those factors play very significant roles in designing forms. In this project the factors are based on Michigan State Timber Properties.

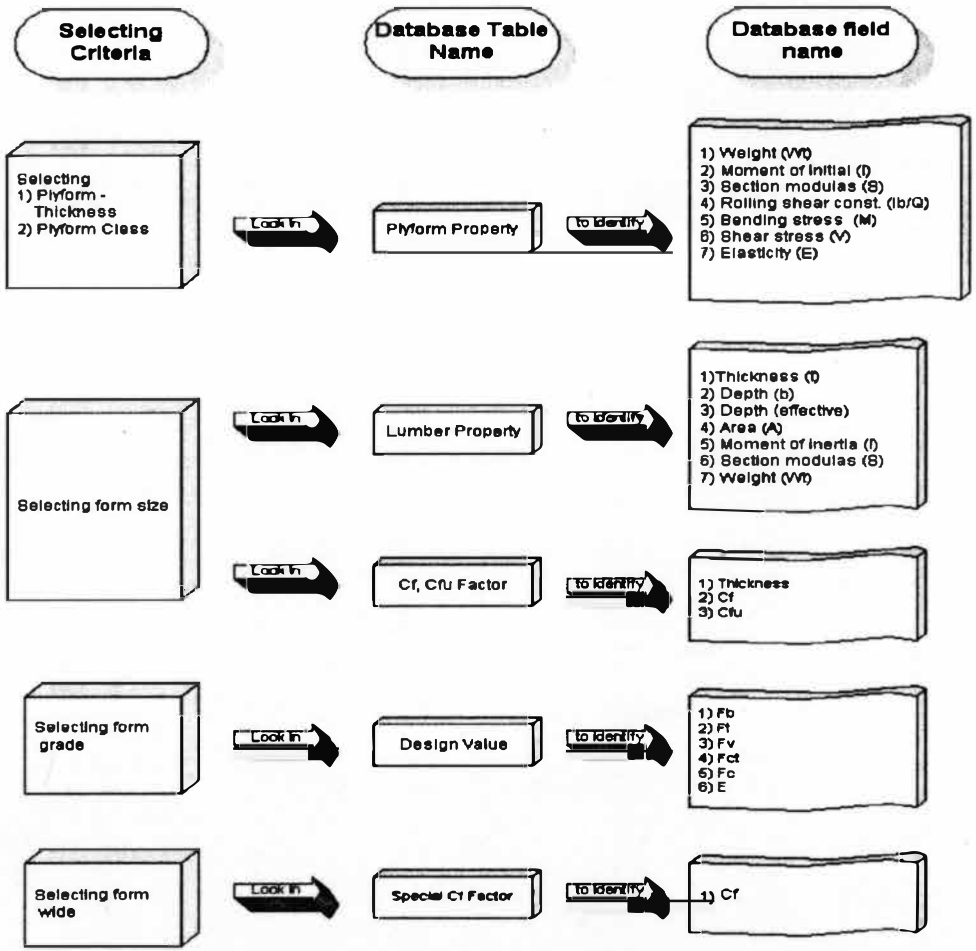


Figure 2. Section Properties and Design Values Selection Process.

Figure 3 shows the main program consists of four design modules , which are (1) Slab Formwork Design, (2) Column Formwork Design, (3) Beam Formwork Design, and (4) Wall Formwork Design. By double clicking on a particular design module, user will begin to design that formwork interactively. The entire design process consists of "event driven activities" that require the interaction between the user and the program. The complete screen layouts for the wall formwork design calculations are shown in Figure 4 and their screen views of detail calculation steps are shown in Figure 5. In the same fashion, the screen layouts of Beam formwork design are shown on Figure 6 and Figure 7, the screen layouts of slab formwork design are shown on Figure 8 and 9, and the screen layouts of column formwork design are shown on Figure 10.

These detail calculations can be seen on the screen in each design step. Inside the program, there is a set of formwork sketch drawings which can be seen at any time on the screen by clicking at the "Help Picture" button, and these sketches explain the definitions of various members and their interrelationships regarding load transfer mechanism.

The calculation processes also let the user to trail-and- error their entering data, design criteria, and redesign as if the results are not satisfactory. The final results including formwork drawing with material sizes and spacings can be seen on the screen, and can be saved in word documents or text formats. Because of the Windows environment, the entire system is user friendly. By integrating Windows applications, the program provides information to end users (contractors and

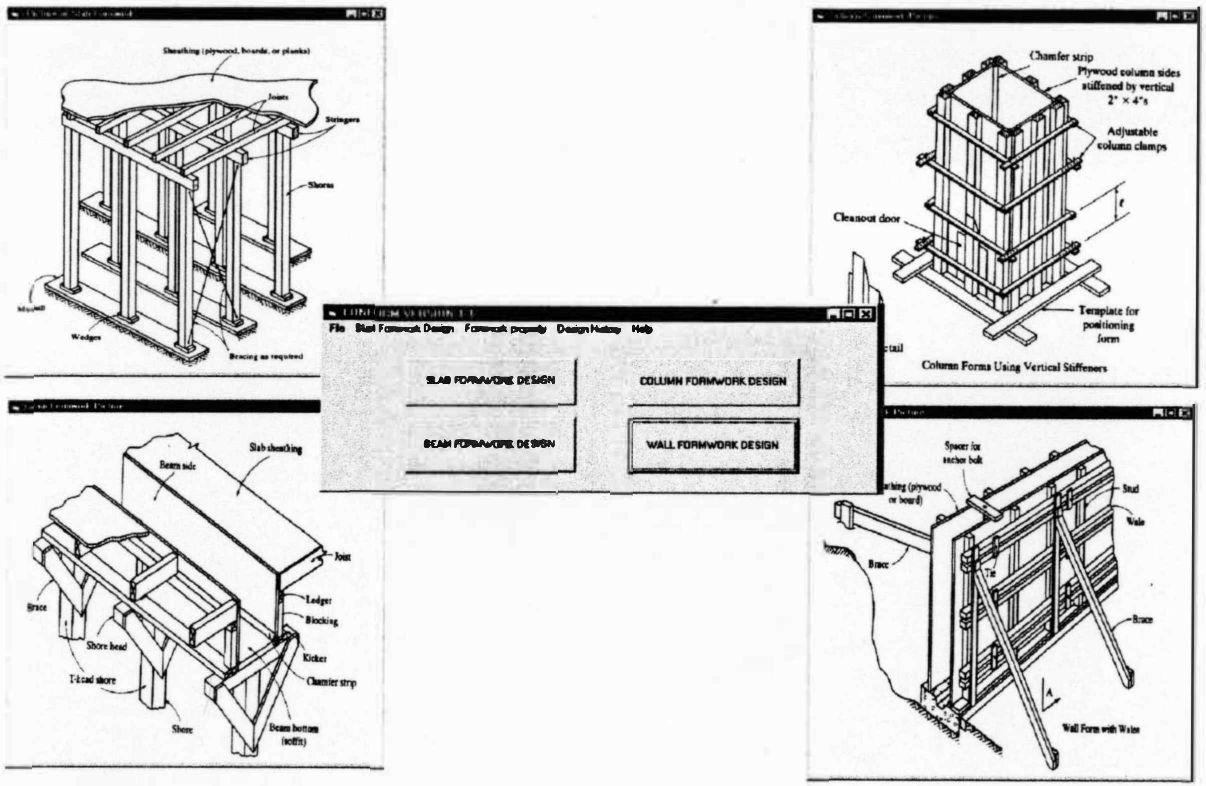
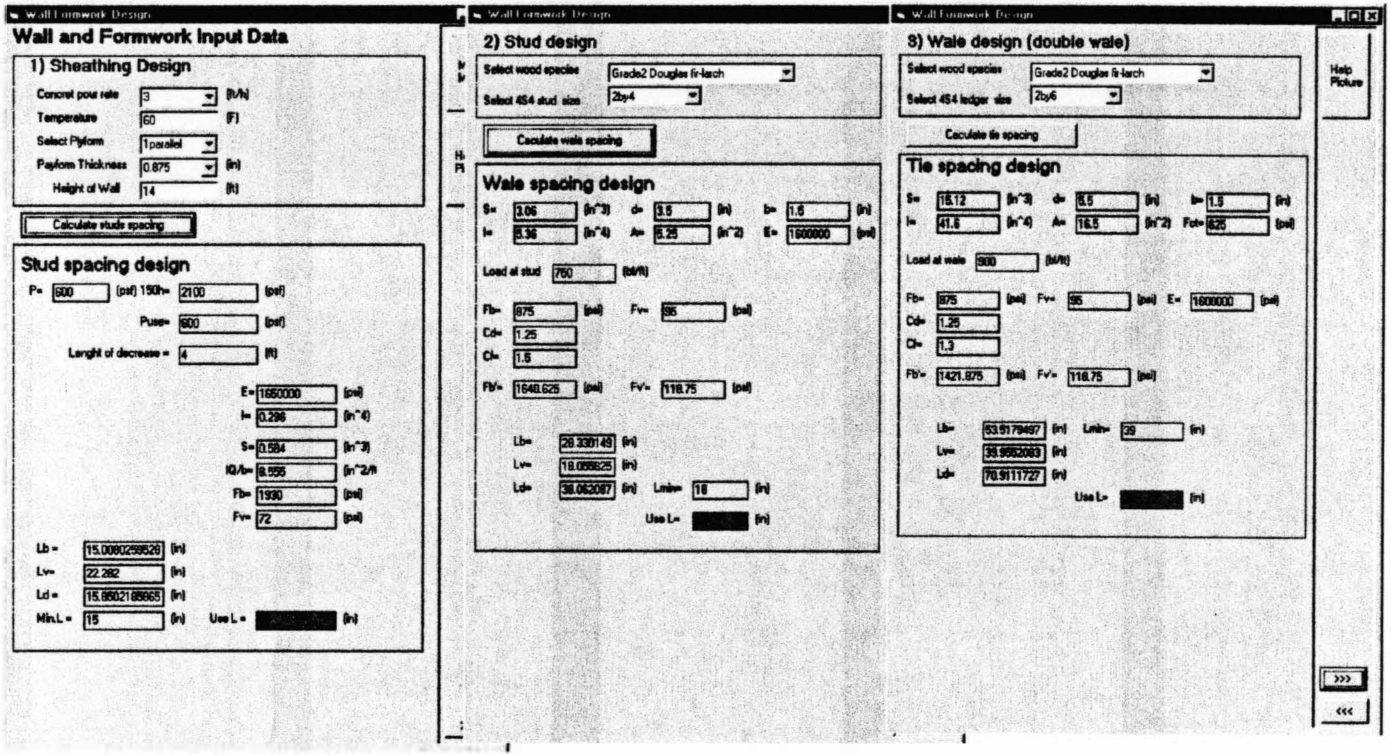


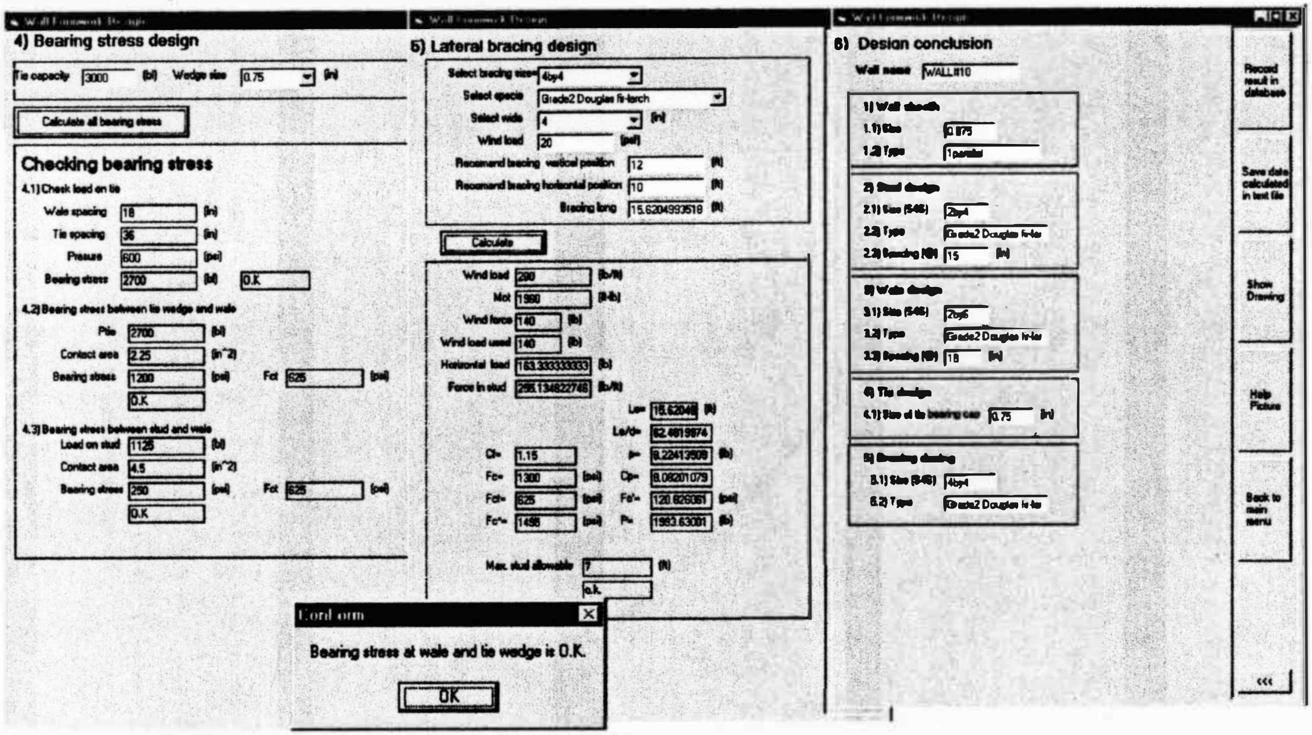
Figure 3. Four Design Modules of *CONFORM.*



(a)

Figure 4. Screen Layout of Wall Form Design Calculations.

Figure 4-Continued



(b)

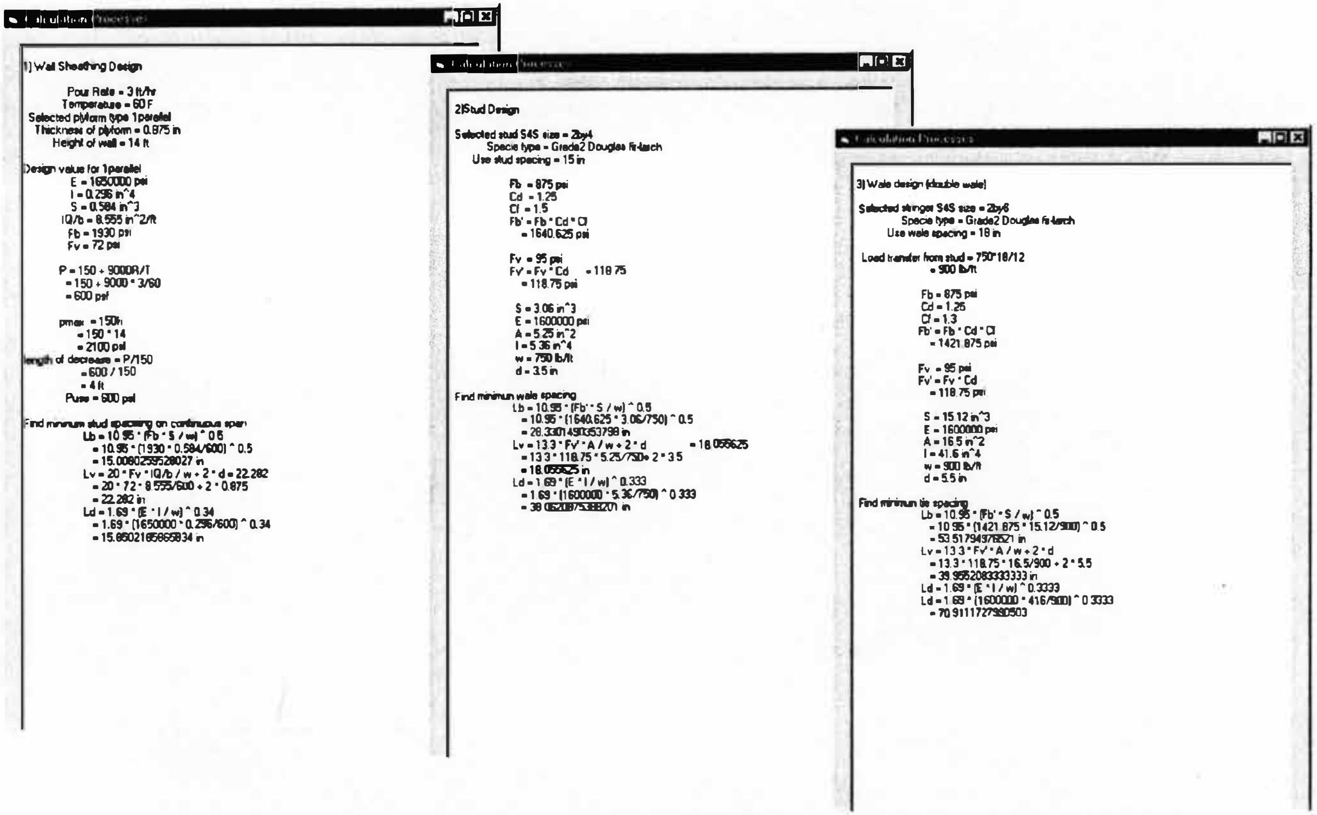
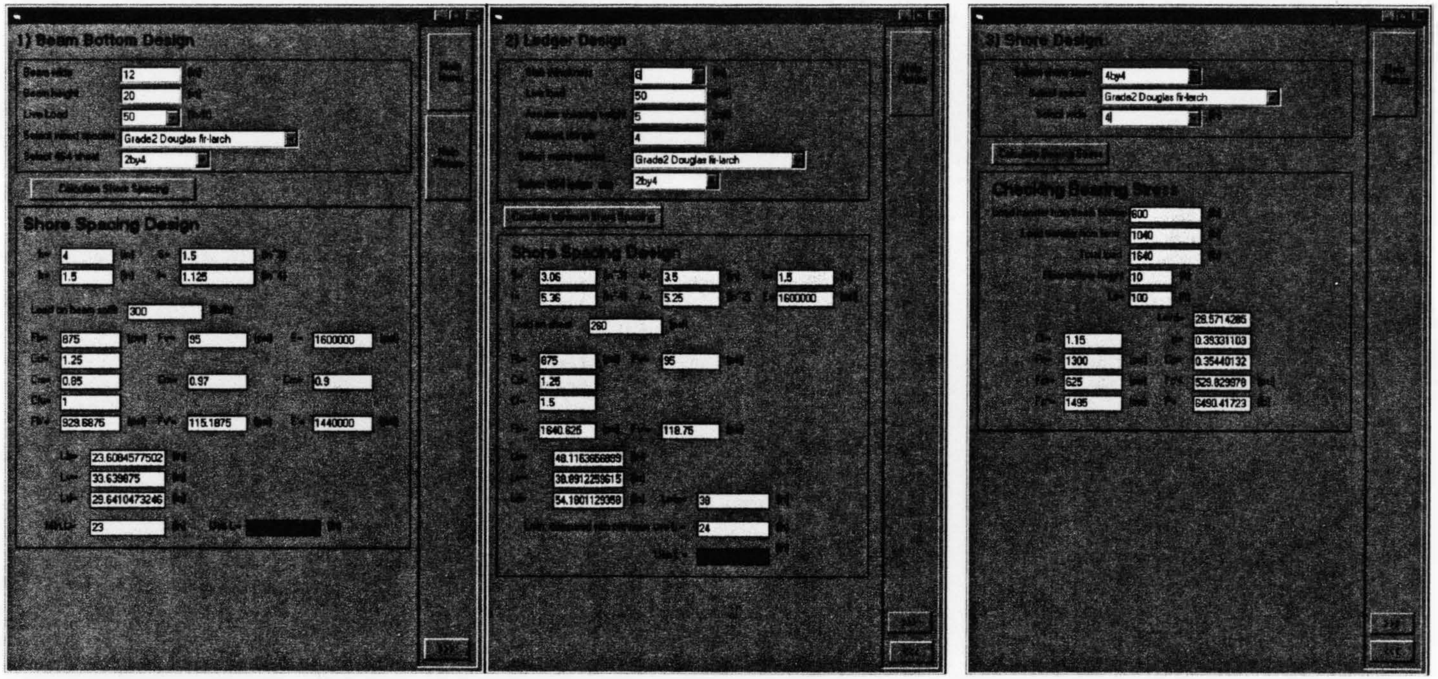


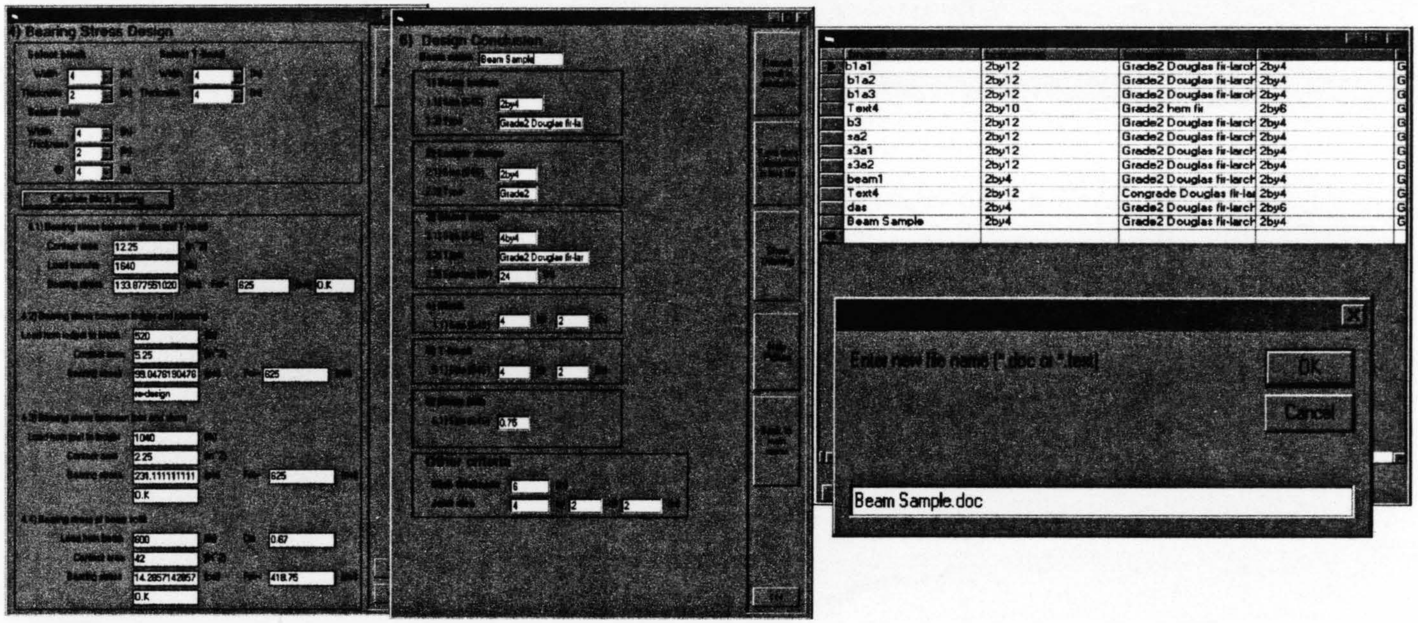
Figure 5. Screen Layout of Wall Form Design Calculation Steps.



(a)

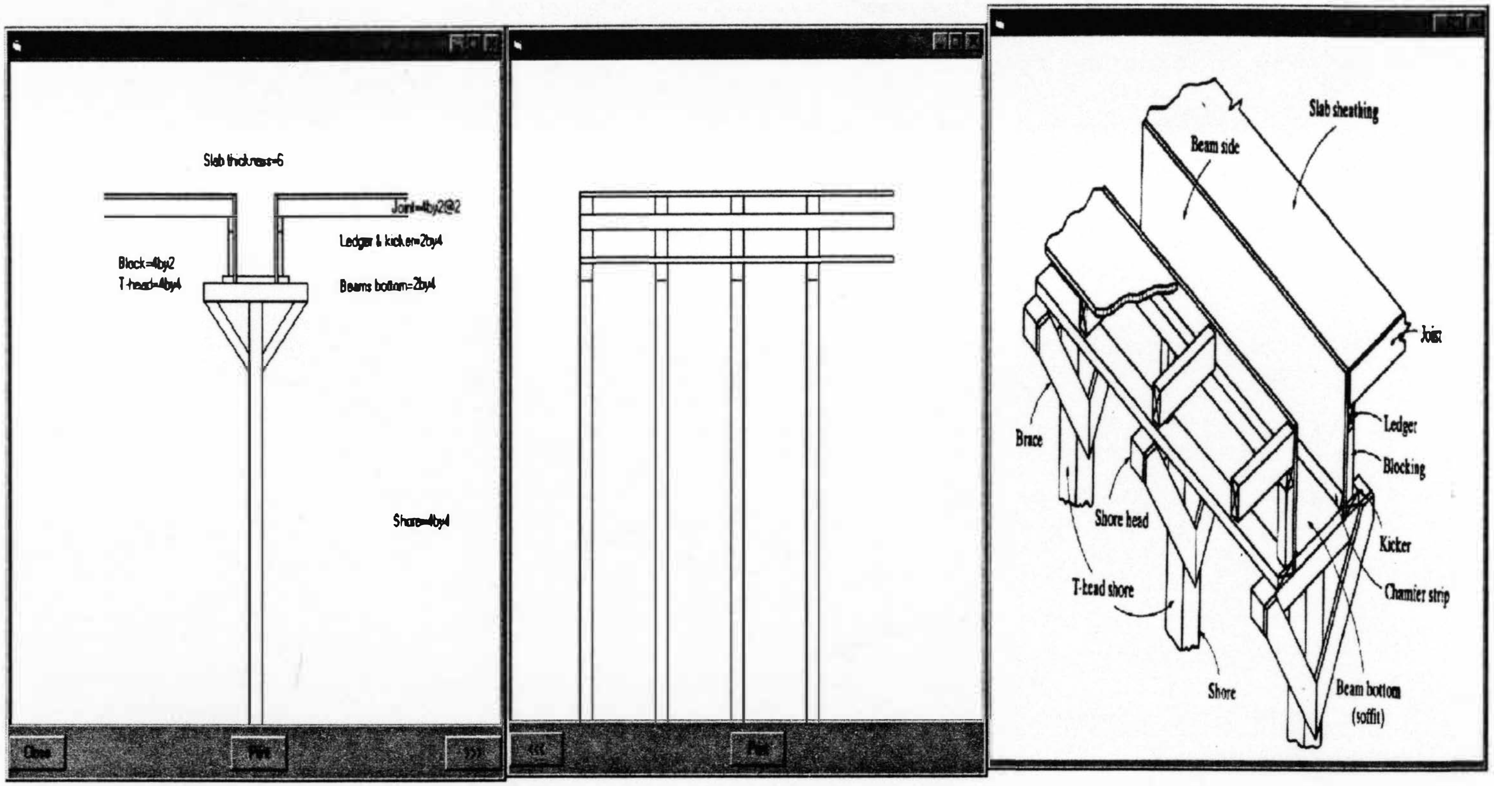
Figure 6. Screen Layout of Beam Form Design Calculations.

Figure 6-Continued



(b)

Figure 6-Continued



(c)

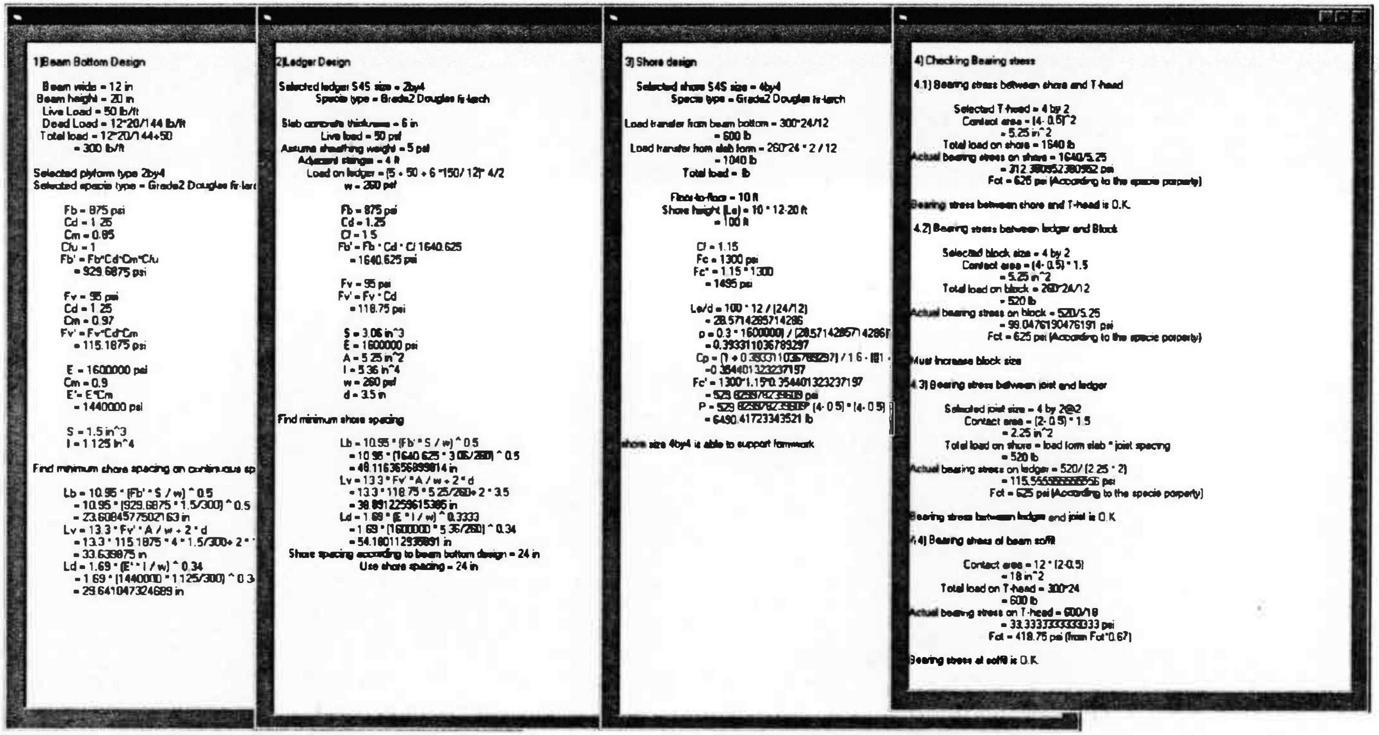
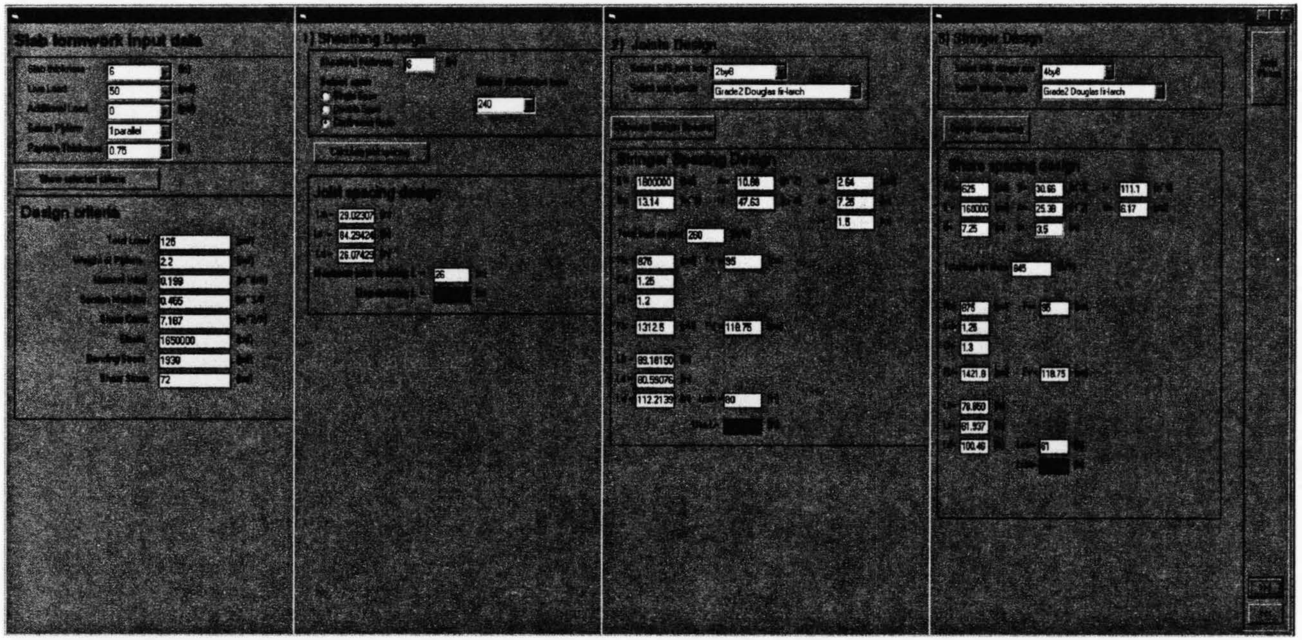


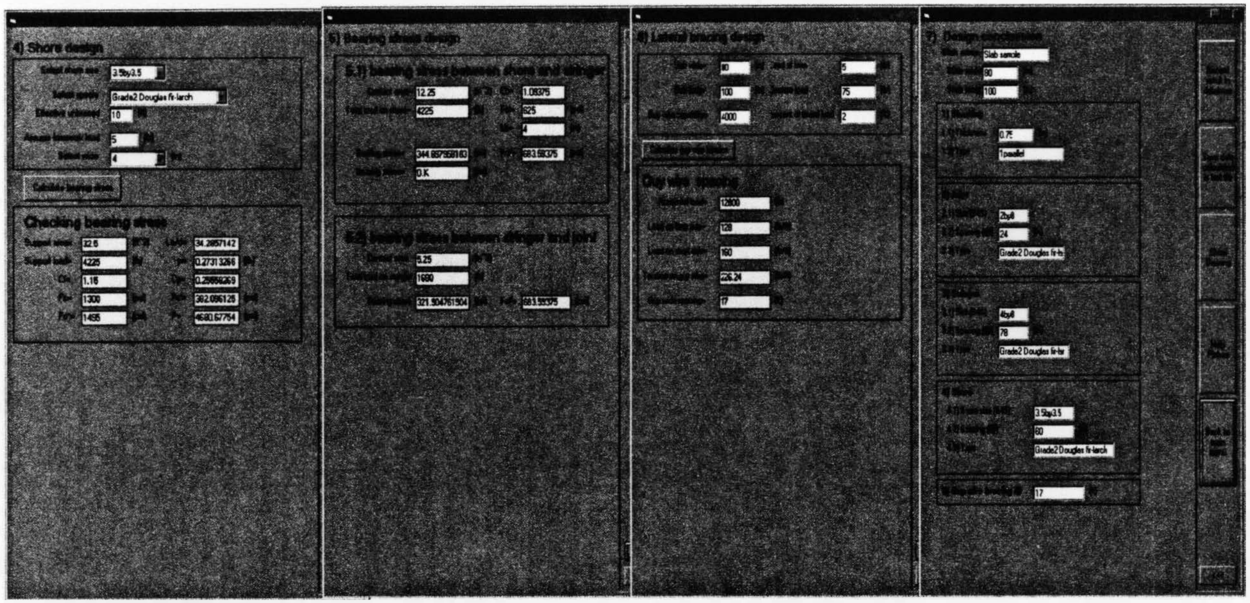
Figure 7. Screen Layout of Beam Form Design Steps.



(a)

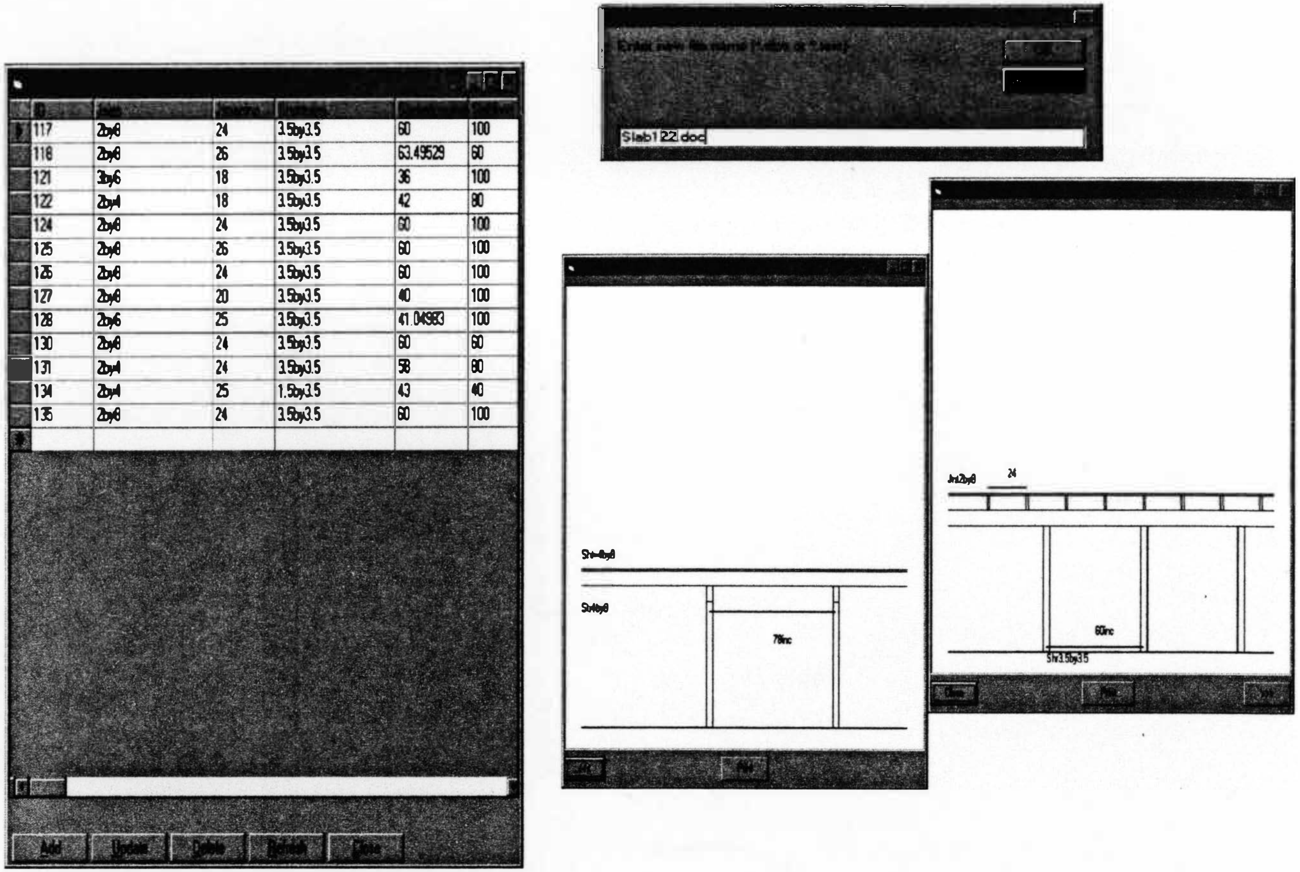
Figure 8. Screen Layout of Slab Form Design Calculation.

Figure 8-Continued



(b)

Figure 8-Continued



(c)

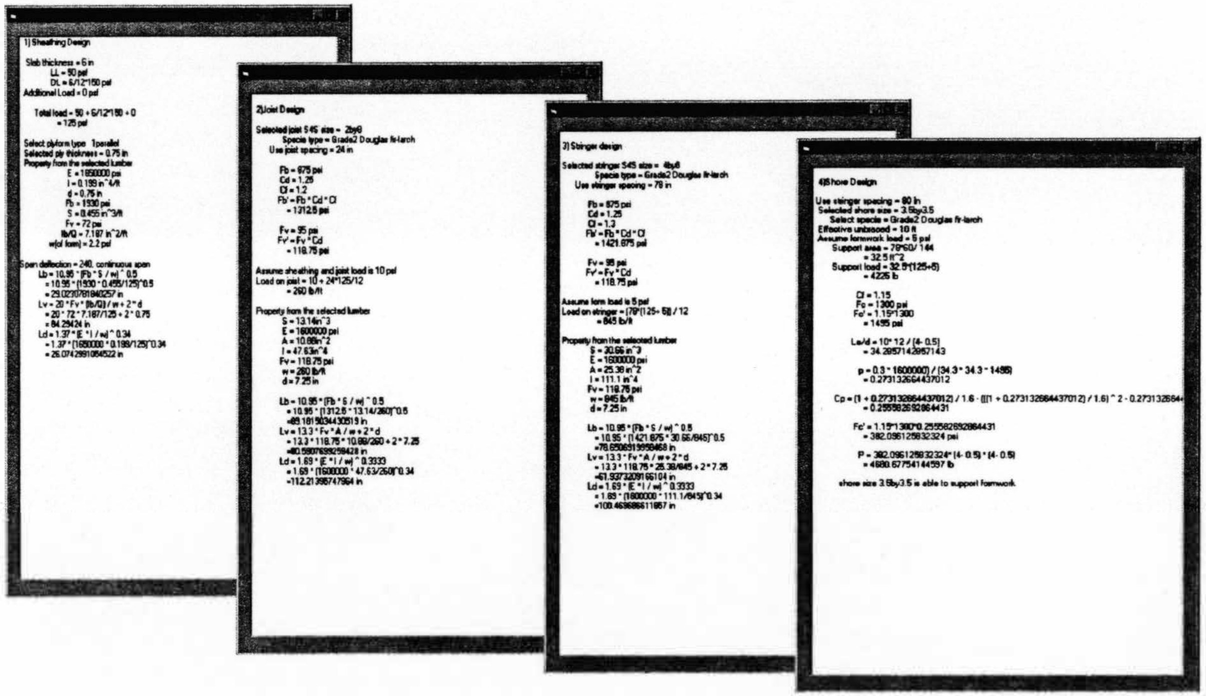
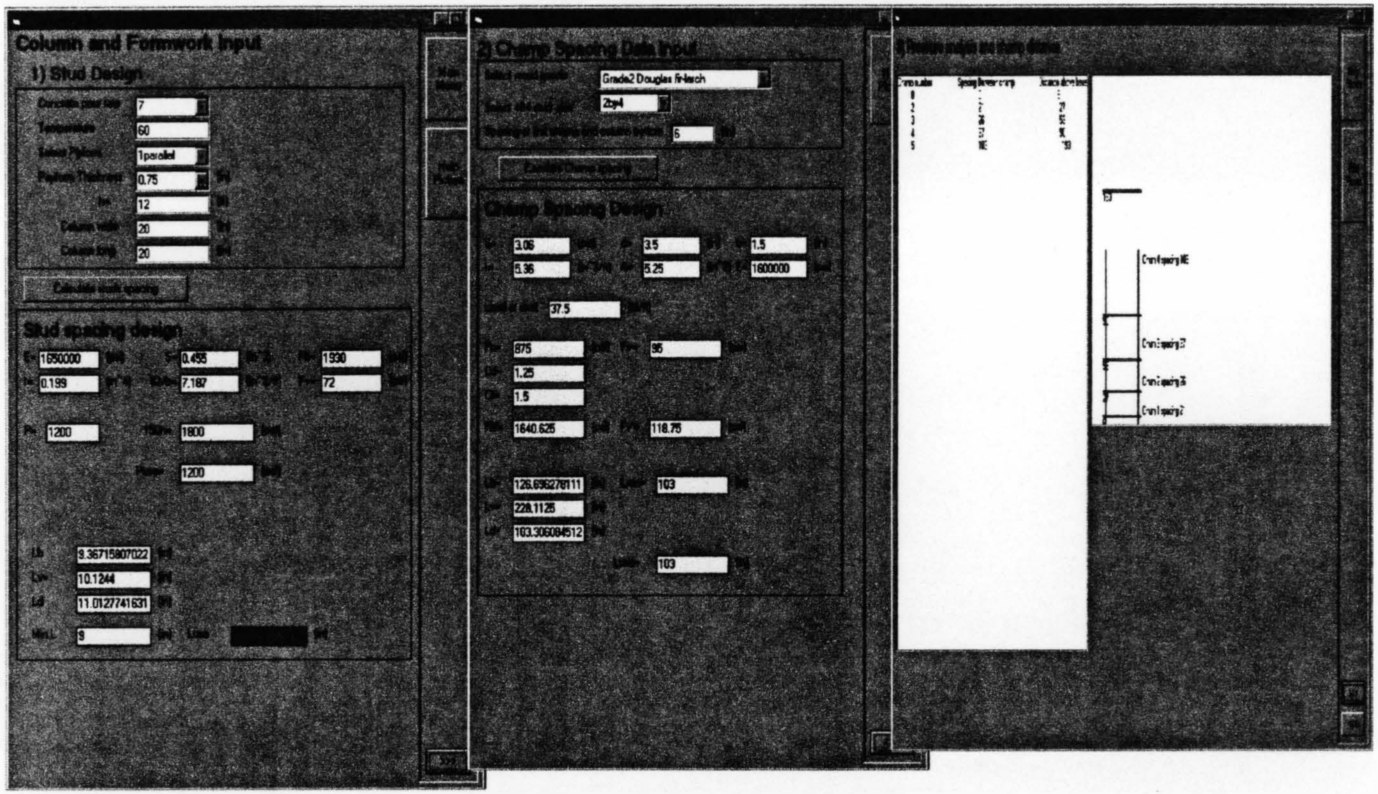


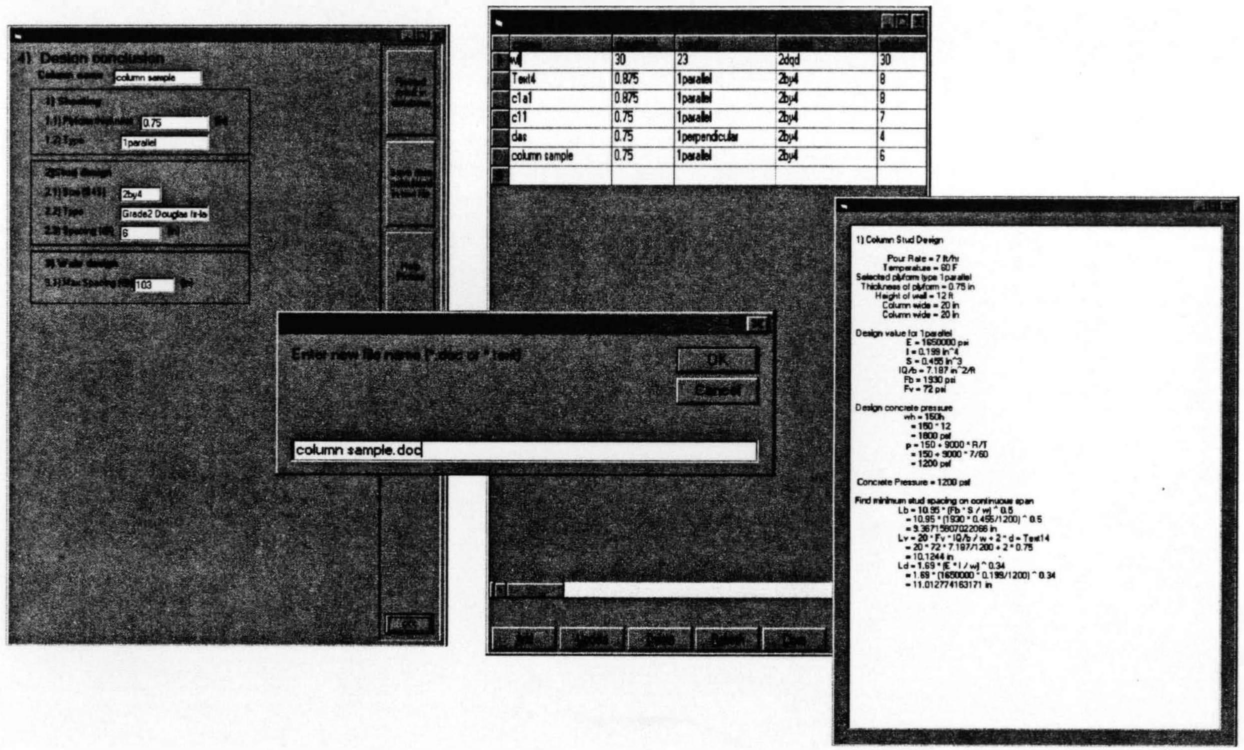
Figure 9. Screen Layout of Slab Form Design Steps.



(a)

Figure 10. Screen Layout of Column Form Design Calculations.

Figure 10-Continued



(b)

engineers) in the way those users like to see it and want to use it, rather than in a single application can present the information. The environment created through this type of development can be called as *container-centric* (Padwick 1996). In this container-centric environment, Access database containing 4 tables mentioned above, belonging to Windows applications are placed in a container which is a Visual Basic platform without users having to concern themselves with the applications that are related to those tables and objects. In other words, integration enables users to concentrate on working with the data instead of with a variety of applications. The system provides a point-and-click environment, so the user does not have to find the application program to open the data file; the file is automatically launched into the correct application for calculations.

Parts of the wood properties that had been included in the program are shown in Table 1 through Table 4 in the following pages.

Using CONFORM

The program starts at the main menu page. The formwork property database can be shown and adjusted by accessing the database from the menu page as well. The user can view the design history, formwork design specification, and wood material properties by using drop menu on this page. The database in this software is actually linked to the entire calculation functions in the program and it is adjustable for appropriate used. The design processes are the "event driven activities " that requires the interaction between the user and program.

Table 1

Plywood Properties

ID	Class	t	Wt	Mo	Modulas	Shear	E	Bending stress	Shear stress
1	1parallel	0.5	1.5	0.077	0.268	5.152	1650000	1930	72
2	1parallel	0.62	1.7	0.129	0.358	5.717	1650000	1930	72
3	1parallel	0.75	2.2	0.199	0.455	7.186	1650000	1930	72
4	1parallel	0.87	2.5	0.296	0.584	8.555	1650000	1930	72
5	1parallel	1	3	0.426	0.7364	9.373	1650000	1930	72
6	1perpendic.	0.5	1.5	0.024	0.129	2.739	1650000	1930	72
7	1perpendic.	0.62	1.7	0.037	0.174	3.094	1650000	1930	72
8	1perpendic.	0.75	2.2	0.092	0.305	4.063	1650000	1930	72
9	1perpendic.	0.87	2.2	0.15	0.421	6.027	1650000	1930	72

Table 1-Continued

ID	Class	t	Wt	Mo	Modulas	Shear	E	Bending stress	Shear stress
10	1perpendic.	1	3	0.27	0.634	7.013	1650000	1930	72
11	2parallel	0.5	1.5	0.075	0.266	4.89	1430000	1330	72
12	2parallel	0.62	1.7	0.12	0.356	5.592	1430000	1330	72
13	2parallel	0.75	2.2	0.197	0.453	6.631	1430000	1330	72
14	2parallel	0.87	2.5	0.3	0.591	7.989	1430000	1330	72
15	2parallel	1	3	0.421	0.754	8.614	1430000	1330	72
16	2perpendic.	0.5	1.5	0.02	0.166	2.726	1430000	1330	72
17	2perpendic.	0.62	1.7	0.032	0.224	3.073	1430000	1330	72
18	2perpendic.	0.75	2.2	0.075	0.391	4.093	1430000	1330	72

Table 1-Continued

ID	Class	T	Wt	Mo	Modulas	Shear	E	Bending stress	Shear stress
19	2perpendic.	0.87	2.5	0.123	0.541	5.997	1430000	1330	72
20	2perpendic.	1	3	0.21	0.81	6.986	1430000	1330	72
21	s1parallel	0.5	1.5	0.078	0.27	4.907	1650000	1930	102
22	s1parallel	0.62	1.7	0.13	0.361	5.257	1650000	1930	102
23	s1parallel	0.75	2.2	0.202	0.463	6.189	1650000	1930	102
24	s1parallel	0.87	2.5	0.317	0.625	7.539	1650000	1930	102
25	s1parallel	1	3	0.47	0.827	7.978	1650000	1930	102
26	s1perpendi	0.5	1.5	0.028	0.178	2.724	1650000	1930	102
27	s1perpendi	0.62	1.7	0.045	0.238	3.072	1650000	1930	102

Table 2

Section Properties

ID	Nom	T	B	Dep	Dress	Area	Moint	Smodulas	Cf	Cfu	Wt
1	2by4	1.5	4	3.5	1.5by3.5	5.25	5.36	3.05	1.5	1	1.27
2	2by6	1.5	6	5.5	1.5by5.5	8.25	20.7	7.55	1.3	1.15	2.00
3	2by8	1.5	8	7.25	1.5by7.25	10.88	47.63	13.14	1.2	1.15	2.64
4	2by10	1.5	10	9.25	1.5by9.25	13.88	98.93	21.38	1.1	1.2	3.36
5	2by12	1.5	12	11.25	1.5by11.25	16.87	178	31.63	1	1.2	4.09
6	3by6	2.5	6	5.5	2.5by5.5	13.75	34.65	12.6	1.3	1.15	3.33
7	3by8	2.5	8	7.25	2.5by7.25	18.12	79.38	21.8	1.2	1.15	4.40
8	3by10	2.5	10	9.25	2.5by9.25	23.12	164.8	35.65	1.1	1.2	5.61
9	3by12	2.5	12	11.25	2.5by11.25	28.12	296.6	52.72	1	1.2	6.84

Table 2- Continued

ID	Nom	T	B	Dep	Dress	A	Moint	Smodulas	Cf	Cfu	Wt
10	4by4	3.5	4	3.5	3.5by3.5	12.25	12.51	7.15	1.5	1	2.98
11	4by6	3.5	6	5.5	3.5by5.5	19.25	48.52	17.64	1.3	1.05	4.67
12	4by8	3.5	8	7.25	3.5by7.25	25.37	111.09	30.65	1.3	1.05	6.17
13	4by10	3.5	10	9.25	3.5by9.25	32.38	230.80	49.9	1.2	1.1	7.86
14	4by12	3.5	12	11.25	3.5by11.25	39.38	415.29	73.83	1.1	1.1	9.56
15	6by6	5.5	6	5.5	5.5by5.5	30.25	76.260	27.72	1	1	7.34
16	6by8	5.5	8	7.25	5.5by7.25	41.25	193.39	51.56	1	1	10.0
17	6by10	5.5	10	9.25	5.5by9.25	52.25	393	82.73	1	1	12.6
18	6by12	5.5	12	11.25	5.5by11.25	63.25	697.09	121.1	1	1	15.3

Table 3

Wood Properties

ID	Specie	Fb	Ft	Fv	Fct	Fc	E
1	Grade2 Douglas fir-larch	875	575	95	625	1300	1600000
2	Grade2 Douglas fir-south	825	525	90	520	1300	1200000
3	Grade2 hem fir	850	500	75	405	1250	1300000
4	Spruce pine fir	875	425	70	425	1100	1400000
5	Congrade Douglas fir-larch	1000	650	95	625	1600	1500000
6	Congrade Douglas fir-south	925	600	90	520	1550	1200000
7	Congrade hem fir	975	575	75	405	1500	1300000
8	Congrade Spruce pine fir	975	475	70	425	1350	1300000
9	Southern 2"-4"	1500	825	90	565	1650	1600000

Table 3-Continued

ID	Specie	Fb	Ft	Fv	Fct	Fc	E
11	Southern 8"	1200	650	90	565	1550	1600000
12	Southern 10"	1050	575	90	565	1500	1600000
13	Southern 12"	975	550	90	565	1450	1600000
14	Congrade 4"	1100	625	100	565	1800	1500000

Table 4

Cf and Cfu Factors

ID	Wide	Thick	Cf	Cfu
1	2by2	2	1.5	1
2	2by3	3	1.5	1
3	2by4	4	1.5	1
4	3by2	2	1.5	1
5	3by3	3	1.5	1
6	3by4	4	1.5	1
7	4by2	2	1.5	1.1
8	4by3	3	1.5	1.1
9	4by4	4	1.5	1
10	5by2	2	1.3	1.1
11	5by3	3	1.3	1.1
12	5by4	4	1.3	1.04
13	6by2	2	1.2	1.14
14	6by3	3	1.2	1.14
15	6by4	4	1.2	1.04
16	8by2	2	1.2	1.14

Table 4 -Continued

ID	Wide	Thick	Cf	Cfu
17	8by3	3	1.2	1.14
18	8by4	4	1.2	1.04
19	10by2	2	1.1	1.2
20	10by3	3	1.1	1.2
21	10by4	4	1.2	1.1
23	12by2	2	1	1.2
24	12by3	3	1.1	1.1
25	12by4	4	1.1	1.2
26	14by2	2	1	1.2
27	14by3	3	1.1	1.1
28	14by4	4	1.1	1.2
29	16by2	2	1	1.2
30	16by3	3	1.1	1.1
31	16by4	4	1.1	1.2
32	18by2	2	1	1.2
33	18by3	3	1.1	1.1
34	18by4	4	1.1	1.2

The program is designed to provide "design forms" as accessing of design steps. The user will be introduced to enter some formwork criteria such as size of wood, current wind load, and pouring rate. Along with the calculation processes, the help picture can be viewed for clarify the design steps.

Formwork Design Processes in the Software

There is a constant linkage between the data input by user and the data in the database system in each step of calculation processes. Basically, the program will use the user's input data to search for the matched information in the database and bring out other important design factors and wood properties.

Results are shown on each design step and let the user adjust the results as desired. The calculation processes also let the user to trail-and- error their entering criteria and redesign as if the results are not satisfied. The detail of formwork calculation process will be discussed in each formwork component after the following sections for more understanding.

The final design results will be concluded in the conclusion page. The conclusion page is linked to the formwork database to store the design results as a formwork design history. The calculation criteria are also stored in term of word documents, rich text file, and other text types that might be further adjusted by the users. However, the user will not be able to adjust or change the final design in the conclusion page. The user must return to the main menu page and start designing the formwork again to come out with alternate results. The program will not let the user manually change the final result without re-calculate the changed criteria.

Another feature in the conclusion page is that the user can display the preliminary formwork shop drawing on screen and print out. The drawing screen will show the wood size and structure. Notice that the preliminary shop drawing still need to be adjusted in final details as the drawing might not significance enough for construction works. The purpose of including preliminary shop drawing in software is to provide the user with graphical idea what his or her formwork should look like. The connection details and finite structure elements are not perfectly shown in the preliminary shop drawing.

In the conclusion page, the user will be introduced to record the final result in the formwork database as design histories. The recording will simply ask the user for a name of formwork. If the name is already existed, the recording device will eject the current formwork design and request the user to change the name. The design history table can be shown in the conclusion page as well. The following section will focus more in the database system and search criteria in the program.

Material Selection by Using Database Integration System

There are 4 database tables that are needed to interact with during the calculation themes: (1) Plyform property table, (2) Lumber property table, (3) Design factor table, and (4) Cu and Cfu factor table. Each database table contains the factor numbers that are related to the user's input criteria. We are now separating selecting case into 4 cases. Each case will required the input data from the user to identify the design values. The design values will be adjusted by the program for the most effective section values.

The selection of plyform thickness and plyform class will imply the program to search in plyform property table. The search is now try to identify the following items in the table which are (a) Weight of plyform, (b) Moment of inertial, (c) Section modulus, (d) Rolling shear, (e) Bending stress, (f) Shear stress (g) Elasticity.

The selection of wood or form size will cause the search engine to look in lumber property table and the Cu Cfu factor table. In the lumber property table, the search engine will try to identify (a) Dressing thickness of the wood size, (b) Dressing Depth of the wood size, (c) Section area, (d) Moment of inertia, (e) Section modulus, and (f) Weight of wood section (Wt).

Meanwhile the search engine will try to identify the (a) Cu and (b) Cfu factor in the Cu, Cfu factors table. The selection of wood grade can identify the capabilities of wood to handle the stress load. Each wood grade will have different capabilities. There are 6 types of stressing factor, which are (a) Fb, (b) Ft, (c) Fv, (d) Fct,(e) Fc, and (f) E.

CHAPTER VII

CONCLUSION

The PC based job-built concrete construction formwork design tool, *CONFORM* is developed by integrating Windows applications- Microsoft Visual Basic 6, Access 97 and Word 97. The program has four main design modules, which are (1) Slab Formwork Design, (2) Column Formwork Design, (3) Beam Formwork Design, and (4) Wall Formwork Design. The entire design process consists of "event drive activities " that require the interaction between the user and the program. The formwork sketch drawings can seen at any time on the screen by clicking at the "Help Picture" button, which explain the definitions of various members and their interrelationships regarding load transfer mechanism. The system provides a point-and-click environment, so the user does not have to find the application program to open the design data files (Access tables); the files are automatically launched into the correct application for calculations. The integration of Windows applications enables the *CONFORM* users to concentrate on working with the design data instead of with a variety of applications. The Access tables containing material properties, section properties, allowable design values and design value adjustment factors can be updated independently without going through the main program. The calculation processes let the user to trail-and- error their entering data, design criteria, and redesign as if the results are not satisfactory. The final results including formwork drawing with material sizes and spacings can be seen on the screen, and be saved in word documents or text format.

The *CONFORM* can have ideal use both at the job site as well as at the engineer's office, and will save significantly the formwork design time. At the job site, *CONFORM* can be run in a Lap-top PC, and by entering the input data based on available sizes of timbers and plywood/plyform formwork construction specifications (member sizes, spacings, etc.) including drawings can be produced both at the PC screen as well as hard copy. This will certainly enhance the construction process by proper and timely utilization of available form construction materials at the job site. The construction inspector to verify the adequacy of the erected concrete formwork can also efficiently use this design tool.

Appendix A

Data Output From CONFORM

"Beam's name is B3"

"***************Data Calculation****************"

"1) Beam bottom Design "

" Beam width = 12 in"
" Beam height = 20 in"
" Live Load = 50 lb/ft"
" Dead Load = 12*20/144 lb/ft"
" Total load = 12*20/144+50"
" = 300.00 lb/ft"

" Selected plyform type 2by12"
" Selected specie type = Grade2 Douglas fir-larch"

" Fb = 875 psi"
" Cd = 1.25"
" Cm = 0.85"
" Cfu = 1.2"
" Fb' = Fb*Cd*Cm*Cfu"
" = 1,115.63 psi"

" Fv = 95 psi"
" Cd = 1.25"
" Cm = 0.97"
" Fv' = Fv*Cd*Cm"
" = 115.19 psi"

" E = 1600000 psi"
" Cm = 0.9"
" E'= E*Cm"
" = 1,440,000.00 psi"

" S = 4.5 in^3"
" I = 3.38 in^4"

"Find minimum shore spacing on continuous span"

" Lb = 10.95 * (Fb' * S / w) ^ 0.5 "
" = 10.95 * (1,115.63 * 4.5/300.00) ^ 0.5 "
" = 44.79 in"
" Lv = 13.3 * Fv' * A / w + 2 * d "
" = 13.3 * 115.19 * 12 * 1.5/300.00+ 2 * 1.5"

"   = 94.92 in"
"   Ld = 1.69 * (E' * I / w) ^ 0.34 "
"   = 1.69 * (1,440,000.00 * 3.38/300.00) ^ 0.34 "
"   = 42.77 in"

"Use shore spacing = 42 in"

"2)Ledger Design"

" Selected ledger S4S size = 2by4"
"   Specie type = Grade2 Douglas fir-larch"

" Slab concrete thickness = 4 in"
"   Live load = 50 psf"
" Assume sheathing weight = 5 psf"
"   Adjacent stringer = 4 ft"
"   Load on ledger = (5 + 50 + 4 *150/ 12)* 4/2"
"   w = 210.00 lb/ft"

"   Fb = 875 psi"
"   Cd = 1.25"
"   Cf = 1.5"
"   Fb' = Fb * Cd * Cf 1,640.63"
"   = 1,640.63 psi"

"   Fv = 95 psi"
"   Fv' = Fv * Cd "
"   = 118.75 psi"

"   S = 3.06 in^3"
"   E = 1600000 psi"
"   A = 5.25 in^2"
"   I = 5.36 in^4"
"   w = 210.00 lb/ft"
"   d = 3.5 in"

" Find minimum shore spacing"

"   Lb = 10.95 * (Fb' * S / w) ^ 0.5 "
"   = 10.95 * (1,640.63 * 3.06/210.00) ^ 0.5 "
"   = 53.54 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/210.00+ 2 * 3.5"

"   = 46.48 in"
"   Ld = 1.69 * (E * I / w) ^ 0.3333 "
"   = 1.69 * (1600000 * 5.36/210.00) ^ 0.34 "
"   = 58.18 in"
"   Shore spacing according to beam bottom design = 42 in"
"   Use shore spacing = 42 in"

" 3) Shore design "

"   Selected shore S4S size = 4by4"
"   Specie type = Grade2 Douglas fir-larch"

" Load transfer from sheathing = 300.00*42/12"
"   = 1,050.00 lb"
"Load transfer from slab form = 210.00*42 * 2 / 12"
"   = 1,470.00 lb"
"   Total load = 4 lb"

"   Floor-to-floor = 10 ft"
"   Shore height (Le) = 10 * 12-20 ft"
"   = 100.00 ft"

"   Cf = 1.15"
"   Fc = 1300 psi"
"   Fc* = 1.15 * 1300"
"   = 1,495.00 psi"

"   Le/d = 100.00 * 12 / (42/12)"
"   = 28.57"
"   p = 0.3 * 1600000) / (28.57)^2 * 1,495.00)"
"   = 0.39"
"   Cp = (1 + 0.39) / 1.6 - (((1 + 0.39) / 1.6) ^ 2 - 0.39/ 0.8) ^ 0.5 "
"   =0.35"
"   Fc' = 1300*1.15*0.35"
"   = 523.25 psi"
"   P = 523.25* (4- 0.5) * (4- 0.5) "
"   = 6,409.81 lb"

"shore size 4by4 is able to support formwork"

" 4) Checking Bearing stress "

" 4.1) Bearing stress between shore and T-head"

"   Selected T-head = 4 by 4"
"   Contact area = (4- 0.5)^2 "
"   = 12.25 in^2"
"   Total load on shore = 2520 lb"
"Actual bearing stress on shore = 2520/12.25"
"   = 205.71 psi"
"   Fct = 625 psi (According to the specie property)"

"Bearing stress between shore and T-head is O.K."

" 4.2) Bearing stress between ledger and Block"

"   Selected block size = 4 by 2"
"   Contact area = (4- 0.5) * 1.5"
"   = 5.25 in^2"
"   Total load on block = 210.00*42/12 "
"   = 735.00 lb"
"Actual bearing stress on block = 735.00/5.25"
"   = 140.00 psi"
"   Fct = 625 psi (According to the specie property)"

"Bearing stress between ledger and block is O.K."

"4.3) Bearing stress between joist and ledger"

"   Selected joist size = 4 by 2@2"
"   Contact area = (2- 0.5) * 1.5"
"   = 2.25 in^2"
"   Total load on shore = load form slab * joint spacing "
"   = 420.00 lb"
"Actual bearing stress on ledger = 420.00/ (2.25* 2)"
"   = 93.33 psi"
"   Fct = 625 psi (According to the specie property)"

"Bearing stress between ledger and joist is O.K."

"4.4) Bearing stress of beam bottom"

"   Contact area = 12 * (4-0.5) "
"   = 42.00 in^2"
"   Total load on T-head = 300.00*42"
"   = 1,050.00 lb"

"Actual bearing stress on T-head = 1,050.00/42.00"
"   = 25.00 psi"
"   Fct = 418.75 psi (from Fct*0.67)"

"Bearing stress at beam bottom is O.K."

"**********************End of data calculation***********************"

Slab Formwork Design Sample

"Slab's name is S3a1"

"******************Data Calculation********************"

"1) Sheathing Design "

" Slab thickness = 6 in"
" LL = 50 psf"
" DL = 6/12*150 psf"
"Additional Load = 0 psf"

" Total load = 50 + 6/12*150 + 0"
" = 125 psf"

"Select ply form type 1parallel"
"Selected ply thickness = 0.75 in"
"Property from the selected lumber"
" E = 1650000 psi"
" I = 0.199 in^4/ft"
" d = 0.75 in"
" Fb = 1930 psi"
" S = 0.455 in^3/ft"
" Fv = 72 psi"
" Ib/Q = 7.187 in^2/ft"
" w(of form) = 2.2 psf"

"Span deflection = 240, continuous span"
" Lb = 10.95 * (Fb * S / w) ^ 0.5 "
" = 10.95 * (1930 * 0.455/125)^0.5"
" = 29.02 in"
" Lv = 20 * Fv * (Ib/Q) / w + 2 * d"
" = 20 * 72 * 7.187/125 + 2 * 0.75"
" = 84.29 in"
" Ld = 1.37 * (E * I / w) ^ 0.34"
" = 1.37 * (1650000 * 0.199/125)^0.34"
" = 26.07 in"

" Use joist spacing = 24 in"

"2)Joist Design"

"Selected joist S4S size = 2by8"
" Specie type = Grade2 Douglas fir-larch"

" Fb = 875 psi"
" Cd = 1.25"
" Cf = 1.2"
" Fb' = Fb * Cd * Cf "
" = 1312.5 psi"

" Fv = 95 psi"
" Fv' = Fv * Cd "
" = 118.75 psi"

" Assume sheath and joist load is 10 psf"
" Load on joist = 10 + 24*125/12"
" = 260.00 lb/ft"

"Property from the selected lumber"
" S = 13.14in^3/ft"
" E = 1600000 psi"
" A = 10.88in^2/ft"
" I = 47.63in^4/ft"
" Fv = 118.75 psi"
" w = 260.00 lb/ft"
" d = 7.25 in"

" Lb = 10.95 * (Fb * S / w) ^ 0.5"
" = 10.95 * (1312.5 * 13.14/260.00)^0.5"
" =89.18 in"
" Lv = 13.3 * Fv * A / w + 2 * d"
" = 13.3 * 118.75 * 10.88/260.00 + 2 * 7.25"
" =80.59 in"
" Ld = 1.69 * (E * I / w) ^ 0.3333"
" = 1.69 * (1600000 * 47.63/260.00)^0.34"
" =112.21 in"

" Use stringer spacing = 78 in"

" 3) Stringer design "

"Selected stringer S4S size = 4by8"
" Specie type = Grade2 Douglas fir-larch"

"   Fb = 875 psi"
"   Cd = 1.25"
"   Cf = 1.3"
"   Fb' = Fb * Cd * Cf"
"   = 1421.875 psi"

"   Fv = 95 psi"
"   Fv' = Fv * Cd "
"   = 118.75 psi"

"Assume form load is 5 psf"
"Load on stringer = (78*(125+ 5)) / 12"
"   = 845.00 lb/ft"

"Property from the selected lumber"
"   S = 30.66 in^3/ft"
"   E = 1600000 psi"
"   A = 25.38 in^2/ft"
"   I = 111.1 in^4/ft"
"   Fv = 118.75 psi"
"   w = 845.00 lb/ft"
"   d = 7.25 in"

"   Lb = 10.95 * (Fb * S / w) ^ 0.5"
"   = 10.95 * (1421.875 * 30.66/845.00)^0.5"
"   =78.65 in"
"   Lv = 13.3 * Fv * A / w + 2 * d"
"   = 13.3 * 118.75 * 25.38/845.00 + 2 * 7.25"
"   =61.94 in"
"   Ld = 1.69 * (E * I / w) ^ 0.3333"
"   = 1.69 * (1600000 * 111.1/845.00)^0.34"
"   =100.47 in"

"   Use shore spacing = 60 in"

" 4)Shore Design "

" Selected shore size = 3.5by3.5"
"   Select specie = Grade2 Douglas fir-larch"
" Effective unbraced = 10 ft"
"Assume formwork load = 5 psf"
"   Support area = 78*60/ 144"

"   = 32.50 in^2"
"   Support load = 32.50*(125+5)"
"   = 4,225.00 lb"

"   Cf = 1.15"
"   Fc = 1300 psi"
"   Fc' = 1.15*1300"
"   = 1,495.00 psi"

"   Le/d = 10* 12 / (4- 0.5)"
"   = 34.29"

"   p = 0.3 * 1600000) / (34.3 * 34.3 * 4by8)"
"   = 0.27"

"   Cp = (1 + 0.27) / 1.6 - (((1 + 0.27) / 1.6) ^ 2 - 0.27/ 0.8) ^ 0.5"
"   = 0.25"

"   Fc' = 1.15*1300*0.25"
"   = 373.75 psi"

"   P = 373.75* (4- 0.5) * (4- 0.5)"
"   = 4,578.44 lb"

"   Shore size 3.5by3.5 is able to support formwork"

" 5) Checking Bearing stress "

" 5.1) Check bearing stress between stringer and shore"
"   Contact area = (4- 0.5) * 3.5"
"   = 12.25 in^2"
"   Total load on shore = 4,225.00 lb"
"Actual bearing stress on shore = 4,225.00/12.25"
"   = 344.90 psi"

"   Cb = (4+ 0.375) /4"
"   = 1.09"
"   Fct = 625 psi"
"   Fct' = 1.09*625"
"   = 681.25 psi"

"   Bearing stress between stringer and shore is O.K."

" 5.2) Check bearing stress between stringer and joist"
"   Contact area = 3.5*1.5"
"   = 5.25in^2"
"   Total load on stringer = 260.00*78/ 12"
"   = 1,690.00lb"
"   Actual bearing stress = 1,690.00/5.25"
"   = 321.90 psi"

"Bearing stress between stringer and joist is O.K."

" 6)Lateral bracing design"

"   Slab wide = 80 in"
"   Slab long = 100 in"
"   Guy wire capacity = 4000 lb"
"   Assume load on formwork = 5 psf"
"   Assume percent lateral load = 2 %"

"   Concrete load = 75 psf"
"   Horizontal load = 0.01 * 2* (75+5) *80*100"
"   = 12,800.00 lb/ft"
"   Load on long side = 12,800.00/100"
"   = 128.00 lb/ft"
"   Load on short side = 12,800.00/80"
"   = 160.00 lb/ft"

"   Tension on guy wire = 160.00* 1.414 = 226.24 psi"
"   Guy wire spacing = 4000/226.24 = 17 ft"

"******************End of data calculation****************** "

"Wall's name is W2s"

"****************Data Calculation*******************"

" 1) Wall Sheathing Design"

"   Pour Rate = 4 ft/hr"
"   Temperature = 90 F"
" Selected plyform type = 1parallel"
"   Thickness of plyform = 0.75 in"
"   Height of wall = 8 ft"

" Design value for 1parallel"
"   E = 1650000 psi"
"   I = 0.199 in^4"
"   S = 0.455 in^3"
"   IQ/b = 7.187 in^2/ft"
"   Fb = 1930 psi"
"   Fv = 72 psi"

"   P = 150 + 9000R/T "
"   = 150 + 9000 * 4/90"
"   = 550 psf"

"   pmax = 150h"
"   = 150 * 8"
"   = 1200 psf"
"Length of decrease = P/150"
"   = 600 / 150"
"   = 4 ft"
"   Use Pressure = 600 psf"

"Find minimum stud spacing on continuous span"
"   Lb = 10.95 * (Fb * S / w) ^ 0.5"
"   = 10.95 * (1930 * 0.455/600) ^ 0.5"
"   = 13.25 in"
"   Lv = 20 * Fv * IQ/b / w + 2 * d = 18.75"
"   = 20 * 72 * 7.187/600 + 2 * 0.75"
"   = 18.75 in"
"   Ld = 1.69 * (E * I / w) ^ 0.34 "
"   = 1.69 * (1650000 * 0.199/600) ^ 0.34 "
"   = 13.88 in"
"   Stud spacing used is 12 in"

"2)Stud Design"

" Selected stud S4S size = 2by4"
" Specie type = Grade2 Douglas fir-larch"

" Fb = 875 psi"
" Cd = 1.25"
" Cf = 1.5"
" Fb' = Fb * Cd * Cf"
" = 1640.625 psi"

" Fv = 95 psi"
" Fv' = Fv * Cd = 118.75"
" = 118.75 psi"

" S = 3.06 in^3"
" E = 1600000 psi"
" A = 5.25 in^2"
" I = 5.36 in^4"
" w = 600.00 lb/ft"
" d = 3.5 in"

" Find minimum wale spacing"
" Lb = 10.95 * (Fb' * S / w) ^ 0.5"
" = 10.95 * (1640.625 * 3.06/600.00) ^ 0.5"
" = 31.67 in"
" Lv = 13.3 * Fv' * A / w + 2 * d"
" = 13.3 * 118.75 * 5.25/600.00+ 2 * 3.5"
" = 20.82 in"
" Ld = 1.69 * (E * I / w) ^ 0.333"
" = 1.69 * (1600000 * 5.36/600.00) ^ 0.333"
" = 41.00 in"
" Use wale spacing = 20 in"

" 3) Wale design (double wale)"

" Selected stringer S4S size = 2by4"
" Specie type = Grade2 Douglas fir-larch"

" Load transfer from stud = 600.00*20/12"
" = 1,000.00 lb/ft"

"   Fb = 875 psi"
"   Cd = 1.25"
"   Cf = 1.5"
"   Fb' = Fb * Cd * Cf"
"   = 1640.625 psi"

"   Fv = 95 psi"
"   Fv' = Fv * Cd"
"   = 118.75 psi"

"   S = 6.12 in^3"
"   E = 1600000 psi"
"   A = 10.5 in^2"
"   I = 10.72 in^4"
"   w = 1,000.00 lb/ft"
"   d = 3.5 in"

" Find minimum tie spacing"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5 "
"   = 10.95 * (1640.625 * 6.12/1,000.00) ^ 0.5 "
"   = 34.70 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 10.5/1,000.00 + 2 * 3.5"
"   = 23.58 in"
"   Ld = 1.69 * (E * I / w) ^ 0.3333 "
"   Ld = 1.69 * (1600000 * 10.72/1,000.00) ^ 0.3333 "
"   = 43.57"
"   Use tie spacing = 20 in"

" 4) Checking Bearing stress "

" 4.1) Checking load on tie and tension stress on tie"

"   Selected wedge size = 1.5"
"   Tie capability = 3000 lb"
"   Wale spacing = in"
"   Tie spacing = 24 in"
"   Pressure used = 600 psf"
" Load transferred to tie = wale spacing * tie spacing * pressure"
"   = 24*0.75*W2s/ 144"
"   = 2,000.00 lb"
" Bearing stress on tie is o.k. (2,000.00 < 3000)"

" 4.2) Bearing stress between wedge and wale"

" Ptie = 2,000.00 lb"
" Contact area = 2 * 1.5 * 1.5"
" = 4.50 in^2"
" Bearing stress = 2,000.00/4.50"
" = 444.44 psi"
" Fct = 625 psi (According to the specie property)"

" Bearing stress between tie and wale is O.K"

"4.3) Bearing stress between stud and wale"

" Total load on stud = load on stud * wale spacing"
" = 600.00*20/ 12"
" = 1,000.00 lb"
" Contact area = 2 * 1.5*1.5"
" = 4.5 in^2
" Bearing stress = 1,000.00/4.50"
" = 222.22 psi"
" Bearing stress between stud and wale is O.K"

" 5)Lateral bracing design"

" Selected bracing S4S size = 2by4"
" Specie type = Grade2 Douglas fir-larch"
" Wind load = 15 psf"
" Vertical distance of bracing = 6 ft"
"Horizontal distance of bracing = 4 ft"
" Actual long of bracing = 7.21 ft"

" Wind load per ft. of wall = 8*15"
" = 120 lb/ft"
" Mot = 120*8/ 2"
" = 480 lb/ft"
" Wind force = 480/8"
" = 60.00 lb/ft"
" Wind load used = 100 lb/ft"
" Horizontal load used = 100*8/6"
" = 133.33 lb"
" Vertical load used = 133.33*7.21/4"
" = 208.26 lb"

"   Cf = 1.15"
"   Fc = 1300 psi"
"   Fc* = 1.15*1300"
"   = 1495 psi"
"   Le/d = 7.81* 12/b-1"
"   = 7.81"

"   p = 0.3 * 1600000) / (31.24)^2 * 1495)"
"   = 0.33"
"   Cp = (1 + 0.33) / 1.6 - (((1 + 0.33) / 1.6) ^ 2 - 0.33/ 0.8) ^ 0.5"
"   = 0.30"
"   Fc'= 1300*1.15*0.30"
"   = 448.50 psi"
"   P = 448.50 * 10.5"
"   = 4,709.25 lb"
"Maximum stud spacing allowable = 4,709.25/208.26"
"   = 22 ft"

"Stud spacing regarding with this bracing is O.K"

"***********End of data calculation****************** "

"Column's name is C3"

"***************Data Calculation****************"

"1) Column Stud formwork Design"

" Pour Rate = 4 ft/hr"
" Temperature = 90 F"
" Selected plyform type 1parallel"
" Thickness of plyform = 0.75 in"
" Height of wall = 12 ft"
" Column wide = 20 in"
" Column wide = 20 in"

" Design value for 1parallel"
" E = 1650000 psi"
" I = 0.199 in^4"
" S = 0.455 in^3"
" IQ/b = 7.187 in^2/ft"
" Fb = 1930 psi"
" Fv = 72 psi"

" Design concrete pressure"
" wh = 150h"
" = 150 * 12"
" = 1800 psf"
" p = 150 + 9000 * R/T"
" = 150 + 9000 * 4/90"
" = 550 psf"

" Concrete Pressure = 1800 psf"

"Find minimum stud spacing on continuous span"
" Lb = 10.95 * (Fb * S / w) ^ 0.5"
" = 10.95 * (1930 * 0.455/1800) ^ 0.5"
" = 7.65 in"
" Lv = 20 * Fv * IQ/b / w + 2 * d = Text14"
" = 20 * 72 * 7.187/1800 + 2 * 0.75"
" = 7.25 in"
" Ld = 1.69 * (E * I / w) ^ 0.34 "
" = 1.69 * (1650000 * 0.199/1800) ^ 0.34 "
" = 9.62 in"
" Stud spacing used is 6 in"

"2)Column champ spacing Design"

" Selected stud S4S size = 2by4"
" Specie type = Grade2 Douglas fir-larch"

" Fb = 875 psi"
" Cd = 1.25"
" Cf = 1.5"
" Fb' = Fb * Cd * Cf"
" = 1640.625 psi"

" Fv = 95 psi"
" Fv' = Fv * Cd "
" = 118.75"
" = 118.75 psi"

" S = 3.06 in^3"
" E = 1600000 psi"
" A = 5.25 in^2"
" I = 5.36 in^4"
" w = 231.25 lb/ft"
" d = 3.5 in"
" b = 1.5 in"

" Find champ spacing"
" Design champ spacing of Champ number 1"

" w = (1800 - 6/ 12 * 150) * 6/12"
" = 862.50"
" Lb = 10.95 * (Fb' * S / w) ^ 0.5"
" = 10.95 * (1640.625 * 3.06/862.50) ^ 0.5"
" = 26.42 in"
" Lv = 13.3 * Fv' * A / w + 2 * d "
" = 13.3 * 118.75 * 5.25/862.50+ 2 * 3.5"
" = 16.61 in"
" Ld = 1.69 * (E * I / w) ^ 0.333"
" = 1.69 * (1600000 * 5.36/862.50) ^ 0.333"
" = 36.33 in"
" Use champ spacing = 16 in"

"Distance from bottom to champ = 22 in"

" Design champ spacing of Champ number 2"

"   w = (1800 - 22/ 12 * 150) * 6/12"
"   = 762.50"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5"
"   = 10.95 * (1640.625 * 3.06/762.50) ^ 0.5"
"   = 28.10 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/762.50+ 2 * 3.5"
"   = 17.87 in"
"   Ld = 1.69 * (E * I / w) ^ 0.333"
"   = 1.69 * (1600000 * 5.36/762.50) ^ 0.333"
"   = 37.85 in"
"   Use champ spacing = 17 in"

"Distance from bottom to champ = 39 in"

" Design champ spacing of Champ number 3"

"   w = (1800 - 39/ 12 * 150) * 6/12"
"   = 656.25"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5"
"   = 10.95 * (1640.625 * 3.06/656.25) ^ 0.5"
"   = 30.29 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/656.25+ 2 * 3.5"
"   = 19.64 in"
"   Ld = 1.69 * (E * I / w) ^ 0.333"
"   = 1.69 * (1600000 * 5.36/656.25) ^ 0.333"
"   = 39.79 in"
"   Use champ spacing = 19 in"

"Distance from bottom to champ = 58 in"

" Design champ spacing of Champ number 4"

"   w = (1800 - 58/ 12 * 150) * 6/12"
"   = 537.50"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5"
"   = 10.95 * (1640.625 * 3.06/537.50) ^ 0.5"
"   = 33.46 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/537.50+ 2 * 3.5"
"   = 22.43 in"
"   Ld = 1.69 * (E * I / w) ^ 0.333"

"   = 1.69 * (1600000 * 5.36/537.50) ^ 0.333"
"   = 42.53 in"
"   Use champ spacing = 22 in"

"Distance from bottom to champ = 80 in"

" Design champ spacing of Champ number 5"

"   w = (1800 - 80/ 12 * 150) * 6/12"
"   = 400.00"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5"
"   = 10.95 * (1640.625 * 3.06/400.00) ^ 0.5"
"   = 38.79 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/400.00+ 2 * 3.5"
"   = 27.73 in"
"   Ld = 1.69 * (E * I / w) ^ 0.333"
"   = 1.69 * (1600000 * 5.36/400.00) ^ 0.333"
"   = 46.93 in"
"   Use champ spacing = 27 in"

"Distance from bottom to champ = 107 in"

" Design champ spacing of Champ number 6"

"   w = (1800 - 107/ 12 * 150) * 6/12"
"   = 231.25"
"   Lb = 10.95 * (Fb' * S / w) ^ 0.5"
"   = 10.95 * (1640.625 * 3.06/231.25) ^ 0.5"
"   = 51.02 in"
"   Lv = 13.3 * Fv' * A / w + 2 * d "
"   = 13.3 * 118.75 * 5.25/231.25+ 2 * 3.5"
"   = 42.86 in"
"   Ld = 1.69 * (E * I / w) ^ 0.333"
"   = 1.69 * (1600000 * 5.36/231.25) ^ 0.333"
"   = 56.34 in"
"   Use champ spacing = 42 in"

"Distance from bottom to champ = 149 in"

"***********End of data calculation***************** "

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