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C. N. Kostem

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SHEAR PUNCHING OF BRIDGE DECKS

by

Celal N. Kostem

Research Project No. 71-12
Overloading Behavior of Beam-Slab
Type Highway Bridges

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16. Abstract

The report summarizes the findings of the research on the susceptibility of reinforced concrete slabs of beam-slab type highway bridges to shear punch failure due to the wheel loads. The investigation included a review of literature on shear punching of bridge decks due to patch loads, and five parametric investigations covering a wide range of slab and wheel loading configurations. The patch loads considered correspond to the wheel loadings of trucks and dollies of special vehicles.

It has been conclusively found that the bridge decks will not undergo shear punch failure due to the single or tandem wheels of overloaded vehicles. The mode of failure of the deck slab is essentially due to the flexural behavior.

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Project 71-12: Overloading Behavior of Beam-Slab Type Highway Bridges

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by

Celal N. Kostem

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ABSTRACT

The report summarizes the findings of the research on the susceptibility of reinforced concrete slabs of beam-slab type highway bridges to shear punch failure due to the wheel loads. The investigation reaffirms the assumptions made in the development of the analysis scheme to predict the overload response of the above mentioned bridges ("The Inelastic Analysis of Beam-Slab Highway Bridge Superstructures," by W. S. Peterson and C. N. Kostem, Fritz Engineering Laboratory Report No. 378B.5, Lehigh University, 1975).

The investigation included a review of literature on shear punching of bridge decks due to patch loads, and five parametric investigations covering a wide range of deck slab and wheel loading configurations. The patch loads considered correspond to the wheel loadings of trucks and the dollies of special vehicles.

It has been conclusively found that the bridge decks will not undergo shear punch failure due to the single or tandem wheels of overload vehicles. The mode of failure is essentially due to the flexural behavior.

to the surface of the cone, excluding the top and the bottom surfaces, exceed a given ultimate tensile stress level.

1.1 Assumptions Made in the Overload Analysis of Bridges

As required in any analytical investigation certain assumptions were to be made in the development of the scheme to predict the overload response of the bridge superstructures. A detailed description of the assumptions made and their implications have been described in Reference 10. All assumptions, if they had limiting characteristics, were cited accordingly. Furthermore the assumptions that are representative of the actual physical phenomenon, which had been verified by previous experimental and analytical investigations, were also elucidated (Ref. 10).

The assumption of prime importance dealt with the mode of inelastic response of the bridge superstructure. It was assumed that the main source of the initiation as well as the propagation of the inelastic behavior, and eventually the damage, of the superstructure was due to the bending of the deck slab and the beams. The accuracy of this assumption has been demonstrated in five comparative case studies. These bridges were field tested elsewhere and reported in the literature. Their overload response and the type of damage were analytically predicted through the tools developed in the parent research program (Ref. 10). The comparisons for all cases have clearly indicated a good agreement between the test and the analytical prediction.

1.2 Problem Statement

A limited number of beam-slab highway bridges were field tested, under simulated design loads, to define lateral load distribution and slab behavior (Ref. 14). It was noted that when the wheels of the test vehicle are near, and especially on, the location of the slab that has been instrumented, through the use of electrical resistance strain gages, there are marked peaks in the slab strain. Some researchers have felt that this may be due in part to the possible trend towards the development of "quasi-shear-punch-cone," and in part due to the local effects produced by the wheel load. It was further believed by some that in the case of the overload vehicles, the shear stresses will increase due to the increase in vehiclular weight and the deck slab will fail through the formation of the "shear punching" rather than the flexural overstressing, or possibly both.

The inclusion of the provisions into the developed analysis scheme that will account for the possibility of shear punching for various levels of nonlinearity and the progression of the damage to the bridge superstructure would require major changes (Ref. 14). The changes, if required, would make the developed analysis scheme so unmanageable that it may be less expensive to have the overload vehicle traverse the bridge and either partially or totally damage the superstructure and have the bridge replaced; rather then prior to the traverse of the vehicle predict the possible damage and either issue or deny the overload permit through the use of the developed analysis scheme. The extraordinary increase in the cost of the prediction of the overload response of the bridge superstructure via an analysis scheme which will inherently include the shear punching as compared to the already developed methodology (Ref. 10) is due to the basic classification of the elasticity problem. The prediction analysis with shear punching leads to inelastic analysis of three dimensional solids with highly irregular geometry, i.e. bridge superstructures. Problems of this complexity have not been attempted as yet. The prediction analysis without shear punching leads to the inelastic analysis of plates, i.e. bridge deck, and beams, which has already been accomplished by the researcher (Ref. 10). However, if the overload vehicles can induce shear punch failure in the bridge deck slab, then the predictions made for the possible damage to the bridge would be totally incorrect. A situation as such would dictate the activation of certain provisions either in the analysis scheme, with or without some gross approximations and consequently with loss of reliability in the results, or the initiation of further research in the control of shear punch failure. All possible alternatives would have led to major investments of funds and time to handle the shear punch problem as far as the overloading of bridge decks is concerned.

It has been decided that rather then undertake a major research on the shear punching, efforts should concentrate on (1) identifying the shear punch failures reported in the literature and relating them to overload vehicles, (2) through simple models, defining the load levels and the size of the patch load area that will induce the shear punch, (3) through analytical studies relating the maximum shear and tensile stresses in the deck slab that are related to shear punching to the maximum tensile and compressive stresses that are related to the cracking or crushing of the concrete due to flexure in order to find out whether the shear punch failure occurs prior to the flexural damage, and finally (4) trying to interpret the source of the high strains recorded in the field testing of the bridges. If the results of the above sub-investigations indicate that the required loading configuration to induce shear punch failure is much in excess of the loading that will induce substantial damage to the deck slab, then no further consideration should be given to the problem area of shear punching of the deck as far as the overloading of highway bridges is concerned (Ref. 6).

1.3 Literature Survey

An extensive literature survey carried out on the general problem area of shear punching has indicated that with very few exceptions the attention has always been focused on the building systems, that is, the punching of the floor slab by the column. To a lesser extent, research was also carried out on shear punching of slab bridges by supporting columns. Mode of interaction of the floor slab with the column does not resemble the overloading of the bridge deck slab by the wheels of the vehicle. Therefore the findings are not pertinent to the problem on hand and thus a review of the literature will not be undertaken in this report. However, to visualize the major differences between column-floor slab versus bridge deck slab-wheel load it may be helpful to study some of the work on floor systems (Refs. 1 and 5). The development of the failure mechanism in column-floor slab systems is totally different from that of the bridge deck. The amount of force and moments to be transmitted are substantially higher than the wheel loads, and the column cross-sectional areas are smaller, in most cases, than the tire print area. Furthermore, it can be clearly visualized that the wheel loads, as transmitted to the bridge deck slab through the tire print, will cause only pressure normal to the top surface of the slab. Thus the uniaxial or biaxial moments applied via columns, as had been done in some research programs, will not be a problem of concern for the bridges.

The reported research that may have some bearing on shear punch of the bridge decks can be grouped into three main sources: (1) The research at Portland Cement Association Laboratories in Skokie, Illinois (Refs. 7 and 8), and (2) the research carried out in Cement and Concrete Association and the Building Research Station in England (Refs. 9 and 13), and (3) recently completed research in Queen's University in Canada (Refs. 2 and 3).

The tests conducted at Portland Cement Association Laboratories employed a tire print composed of two half circles and a rectangular connecting section, as shown in Figure 3 (Ref. 7). The bridge model was a scaled down version of a typical superstructure that can be encountered in practice. In order to induce punching shear failure, depending upon the size of the contact area, "wheel loads" of 15-30 kips had to be applied. Considering the scale factor involved, as explained in Reference 7, this would correspond to wheel loads of 60-120 kips. Needless to say this is substantially in excess of the wheel loads encountered in practice.

The experimental studies carried out at Building Research Station in England also employed scaled down models (Ref. 13). The results of this research, which need not be duplicated here, also revealed that in order to develop shear punch failure, a substantial amount of load needs to be applied over a very small area. These results indicated that, at least for the bridge configurations considered, failure of the deck slab is due to flexure.

After completion of the research reported in Chapter 2 of this report, two new papers appeared in the technical journals which deal with the slab shear strength and more specifically the shear punching (Refs. 2 and 3). The experiments carried out have indicated that for an orthotropically reinforced bridge deck slab there is a factor of safety of approximately 22 against the punching shear failure as compared to the design wheel load (Ref. 2). If an impact factor of 0.3 is applied to the wheel load, then the factor of safety is reduced to 17. In view of the factor of safety against flexural failure of the bridge deck, which is substantially less than the above values, it can again be concluded that for all practical purposes shear punching of the deck will not take place.

All the studies reported above had indicated that the possibility of shear punching, even the possibility of the vertical shear stresses to alter the form of failure assumed in the parent research program previously reported, is less than probable. These studies were confined to limited geometries of the bridge deck, loading and concrete strength. The parametric studies reported in Chapter 2 shed light on how the shear punch resistance of the bridge deck varies as different design parameters are altered within practical limits.

2. SHEAR PUNCHING SUSCEPTIBILITY OF BRIDGE DECKS

Determination of the shear punch susceptibility of the bridge decks can be undertaken through the development of simple models that simulates the formation of the shear punch failure mechanism. The concrete strength, slab thickness, and wheel load corresponding to this failure can than be scrutinized to identify possible bridge and vehicle configurations. If it can be determined that there is a fair possibility of the development of shear punching for realistic wheel load and tire configurations, then the research on the Overload Behavior of Beam-Slab Highway Bridges with Prestressed Concrete I-Beams needs to be modified (Ref. 10).

The shear punch develops due to the presence of a patch load of high intensity on the slab surface. The intensity of this load is equal to the tire pressure while the size and the shape of the patch is the same as the tire print, i.e. contact area. The corresponding wheel load can be computed by multiplying the tire print area by the tire pressure. Since the shear punch resistance is proportional to the "shearing surface" of the slab and the shearing surface is proportional to the perimeter of the tire print, it can be stated that the shear punch resistance is proportional to the tire print perimeter.

A critical parameter, probably the least known, is the shape and size of the tire print. Limited studies have indicated that, as expected, the tire print is related to the tire size as well as tire pressure (Ref. 12). It can be conservatively stated that if the print is considered to have a rectangular shape, then the print size for truck tires will be greater than 5 in. by 7½ in. Furthermore, a detailed inspection of the reporting of overload vehicles has indicated that as the vehicular weight increases the tires employed tend to be wide and low pressure tires (Ref. 17). In addition, in order to distribute the load more uniformly, overload vehicles tend to have many wheels as compared to common design vehicles, for example HS20-44. The overload vehicles with multiple dollies having multiple axles can even have a total number of wheels in excess of 100.

Another important parameter in the development and determination of the shear punch failure mechanism is the angle between the shearing surface and the normal to the slab, indicated as ϕ in Figure 1. This angle has been for many years intuitively, and also conservatively, assumed to be 45 degrees (Ref. 11). Recent experimental and analytical investigations have indicated that the angle is closer to 65 degrees. Inspection of Figure 1 indicates that as the angle increases the surface of the shear cone, ignoring the top and bottom surfaces, will also increase. Since the resistance to the shear punching is proportional to the resisting surface area, the possibility of shear punching will be reduced. In the determination of the load that induces the shear punching in the slab, the contribution of the reinforcing bars was not included. This leads to highly conservative results. Some researchers have developed relationships between angle ϕ and f'_c. For the sake of conservatism these relationships are not included in the reported study.

2.1 Parametric Study No. 1

In order to have a numerical comparison of the magnitude of the wheel loads required for slabs of various thicknesses and various concrete strengths, an initial parametric study was undertaken.

The parametric study employed 8 different concrete strengths for the slab (f'_c = 2500, 3000, 3500, 4000, 4500, 5000, 5500 and 6000 psi). Slab thickness was also varied from 6 to 8½ inches with ½ inch increments, resulting in 6 different slab thicknesses. Since the tire print is a variable that governs the failure mechanism, 6 different print sizes were considered: 5 in. by 5 in., 10 in. by 10 in., 20 in. by 20 in., 5 in. by 20 in., 5 in. by 40 in. and 10 in. by 20 in. These prints cover a wide range of contact areas, 5 in. by 5 in. being almost unrealistically small and 5 in. by 40 in. roughly approximating the overlapping influence of two tandem wheels.

In the parametric study two other parameters were varied, namely the shape of the contact area and the angle of the shear cone. The cases investigated were:

(1) Elliptic print, ϕ = 0 degrees

(2) Rectangular print, ϕ = 0 degrees

(3) Elliptic print, ϕ = 45 degrees

(4) Rectangular print, ϕ = 45 degrees

(5) Elliptic print, ϕ = 65 degrees, and

(6) Rectangular print, ϕ = 65 degrees.

Inspection of the above cases indicates that when the shear cone has an angle of 0 degrees, i.e. cylindrical punch, unrealistically conservative results will be obtained. Furthermore when the print size is "square," e.g. 5 in. by 5 in. print, then the elliptical print deteriorates into a circular print since the width and length of the ellipse are equal (Fig. 2).

Through simple algebraic and trigonometric relations the shear surface area (Fig. 1) can be computed considering the shape and size of the print, thickness of the slab and the angle of the shear cone (see the appendix). If this area is denoted as A_s, and if the shear stress capacity, v_{uc}, is taken as $v_{uc} = 3.4 \sqrt{f'_c}$ (Ref. 15) then the load that can induce the shear punching, i.e. wheel load, can be estimated as $P_w = A_s \cdot v_{uc}$. Since the tire print, i.e. the contact area, is assumed for each case investigated, the tire pressure can be obtained by dividing the wheel load by the corresponding contact area.

Tables 1 through 8 give the results of this parametric study. Inspection of the tables leads to interesting conclusions. For example, if it is assumed that a 7½ inch thick concrete deck with $f'_c = 4000$ psi (Table 4) is subjected to a very severe loading condition of 5 in. by 5 in. contact, and also if the values corresponding to cylindrical punch are not considered, being extreme lower bound and unrealistic, then the following results can be extracted:

Print Shape	Ø (degrees)	Wheel Load (kips)	Tire Pressure (psi)
elliptic	45	63	3226
elliptic	65	107	5440
rectangular	45	81	3226
rectangular	65	136	5440

Since contact areas are closer to super-ellipse, it is possible to average the values obtained for ellipse and rectangle for given Ø. This averaging results in the following:

Ø (degrees)	Wheel Load (kips)	Tire Pressure (psi)
45	72	3226
65	121	5440

The above values indicate the impossibility of the shear punch. It is necessary to have a wheel load of at least 72 kips, and more realistically 121 kips, to induce the shear punching. These load levels are much in excess of any practical limit. However, if one assumes that by accident load levels of this magnitude are attained, this time because of the dependency of the shear punch on contact area, it will be necessary to have tire pressures of 3226 psi, or more realistically 5440 psi. These are rather high as far as the pressurization of the tires is concerned. Thus detailed inspection of Tables 1 through 8 clearly indicates that, even though all the reported values are the conservative values, the shear punch of the bridge deck slab is not possible either due to extremely high tire pressure and/or extremely high wheel load requirements.

2.2 Parametric Study No. 2

As can be noted in Parametric Study No. 1, the force required to induce the shear punching in the deck slab is dependent on the geometry of the tire print. To supplement Parametric Study No. 1 by using another model, a new print geometry was chosen. The shape of the contact area is shown in Figure 3. This particular contact area geometry was proposed by Johannes Moe of Portland Cement Association Laboratories in 1961 (Ref. 8). In addition to analytical studies, experiments were also carried out to determine the shear punching of the reinforced concrete slabs (Ref. 7). Again by using the basic geometrical relations it is possible to determine the shear surface to which the shear cone will be subjected (see the appendix). Furthermore, the parametric study can, and did, include variables such as concrete strength, slab thickness and the shear cone angle (ϕ). The corresponding tire pressures and wheel loads can be seen in Tables 9 through 16. In these tables the variable L indicates, as shown in Figure 3, the length of the contact area. If the cylindrical punch, i.e. Ø = 0 degrees, is considered as extreme lower bound values and not included in the assessment, the remaining values still indicate that it requires a substantial wheel load to induce the shear punch. For example if it is assumed that the slab is 7½ in. thick with concrete strength of f'_c = 4000 psi, and if the length of the tire print is assumed to be 10 inches, the following values can be extracted:

Ø (degrees)	Wheel Load (kips)	Tire Pressure (psi)
45	81	1555
65	125	2387

As has been noted in Parametric Study No. 1, the attainment of wheel loads and tire pressures of this magnitude are impractical.

It should be further noted that this model, as in the first parametric study, has not considered the contribution of the reinforcing bars. Inspection of Tables 13 through 16 indicates that there are tire pressures marked with an asterisk. These are the tire pressures that are greater than 10,000 psi.

2.3 Parametric Study No. 3

This parametric study employed the results of the research carried out for shear strength in punching shear of the slabs by square columns (Ref. 8). Even though it has been previously stated that the failure mechanism for the punching of the floor slab by the column is quite different from punching of the bridge deck slab by the wheel load, it has been shown that the use of the findings of the above referred research can yield some useful results. The research has been carried out for square shaped columns, in this case tire prints. The applicability of the findings has been reported in Reference 7. It has been observed that the obtained punching shear resistance of the decks is quite conservative as compared to those experimentally obtained (Ref. 7).

It had been proposed that if the size of the print is r by r, and slab thickness is d, then the shear stress capacity is

$$v_{uc} = (9.23 - 1.12\ r/d) \sqrt{f'_c} \qquad \text{for } r/d \leqq 3$$

and

$$v_{uc} = (2.5 + 10\ d/r) \sqrt{f'_c} \qquad \text{for } r/d > 3$$

By employing the above formulae for the shear strength and considering various sized square tire prints for various strengths of concrete and various slab thicknesses, Tables 17 through 24 have been developed. In these tables, as in the previous tables, wheel loads and the corresponding tire pressures have been tabulated for ϕ = 0, 45 and 65 degrees. It should again be noted that $\phi = 0°$ corresponds to an extreme lower bound value, with no physical significance. In the establishment of these tables if the tire pressure exceeded 10,000 psi, the value of 9,999 psi is printed. The use of these tables need not be illustrated through a numerical example since their use is identical to that of the previously described parametric studies. However, a study of the tables clearly indicates that again shear punch failure of the bridge decks is not possible due to the required extreme tire pressure and/or wheel loads.

2.4 Parametric Study No. 4

This parametric study was undertaken to relate the peak shear stress and tensile stress that develop at the vicinity of the slab under the wheel load to the peak concrete tensile stress or compressive stress in the slab. This study provides the guidelines as to will the slab undergo flexural cracking, or crushing, first or will it fail due to the shear punching.

In order to obtain the required stress values the bridge slab was modeled as plane strain strip, and discretized in depth and along the spacing of the beam using finite element method (Ref. 4). A typical finite element discretization used is shown in Figure 4. Throughout the investigation 2 inch concrete cover over reinforcing bars were assumed for the top of the slab, and 1 inch for the bottom. Beam spacings of 5, 7, 8 and 9 ft. were used. The slab thicknesses were varied from 6 to 9 inches with 1 inch increments. Concrete strengths considered were f'_c = 3500 psi and 4500 psi. The slab reinforcement was provided in accordance with the current design recommendations (Refs. 15 and 16). For each slab configuration three different tire print widths were considered; 5, 10 and 15 inches. Furthermore the wheel load was placed in two possible locations, at the midspacing of the beams and near the flange of the beam. This has totaled (4 spacings) x (4 slab thicknesses) x (2 concrete strengths) x (3 tire print widths) x (2 wheel locations) = 192 case studies. The case studies have resulted in approximately 1,200,000 data points of significance as far as the investigation is concerned. The tabulation of even remotely related values will increase the volume of this report by many orders of magnitude. Therefore, only the overall summary of the parametric study will be presented herein:

(1) (shear punch possibility) / (concrete crushing possibility) ratio is about 11.

(2) (shear punch possibility) / (concrete cracking possibility) ratio is about 19.5, or higher.

(3) no meaningful comparisons can be carried out relating the shear punching to the yielding of reinforcing bars. The reinforcing bar stresses are very low to consider any possibility of yielding before substantial cracking of the deck slab concrete.

In summary the result of this exhaustive parametric investigation supports the previous parametric studies, i.e. the possibility of shear punching of the bridge deck slabs is, as far as the wheel loads are concerned, not probable. The safety factors obtained are also in agreement with those reported by Batchelor (Ref. 2).

2.5 Interpretation of Peak Strains in Field Testing of Bridges

The strain build-up in the slab under the wheel load can be due to a number of reasons. Their contribution to the overall phenomenon can not be quantified without undertaking a detailed investigation. An incomplete listing of possible reasons is:

(1) Under the patch loading the slab undergoes a local bending. The intensity of the bending moment gradient is quite substantial as compared to any moment gradient throughout the slab. This behavior can be demonstrated both mathematically, employing the theory of elasticity, and numerically, employing finite element method.

(2) Under or near the immediate vicinity of the wheel load additional membrane, i.e. in the plane of the slab, strains develop. These strains are due to Poisson's ratio and the tire pressure. The magnitude of these strains is somewhat less than that of the local bending of the deck slab.

(3) If the instruments employed in the recording of the strains do not have "filtering" devices, due to the immediate build up and decline of the strain recordings, the recorded value <u>may</u> look somewhat greater than the actual strain in the instrumented point. The likelihood of the attainment of high strains due to this reason is rather dubious; nevertheless, without proper examination of the signaling and the recording system it can not be ruled out.

3. CONCLUSIONS

The detailed survey of the literature and four parametric studies have indicated that the bridge deck slabs resistance to failure due to shearing punch is many orders higher than their resistance to flexural failure. Studies have been conducted for single or overlapping multiple wheel loadings. In order to develop shearing punch failure, either the wheel load and/or the tire pressure need to be extremely high. Loads of this magnitude can not be attained either through regular or through overloaded vehicle configurations.

The investigation has also indicated that the assumptions made in the research project Overloading Behavior of Beam-Slab Type Highway Bridges are correct. The inclusion of the shear punching-like phenomenon into the overall analysis scheme, which is based on the flexural behavior, can not be justified.

4. APPENDIX

GEOMETRICAL PROPERTIES OF "SHEAR CONES"

1. Rectangular Tire Print of 2A by 2B (See Fig. 1)

   A_c = Contact Area = 4(A + B)

   A_s = Shear Surface, H = slab thickness

   1.1 $\phi = 0°$

   $A_s = 4\ H\ (A + B)$

   1.2 $\phi = 45°$

   $A_s = 4\ H\ (A + B + H)$

   1.3 $\phi = 65°$

   $A_s = 4\ H\ (A + B + 2.1445\ H)$

   P_w = (Wheel Load) = $v_{uc}\ A_s$

   P_t = (Tire Pressure) = $P_w\ /\ A_c$

2. Elliptical Tire Print of 2A by 2B (See Figs. 1 and 2)

   $A_c = 3.1416\ A \cdot B$

   2.1 $\phi = 0°$

   $A_s = 3.1416\ (A + B)\ C$

   where $C = 1 + R^2\ /\ 4 + R^4\ /\ 64 + R^6\ /\ 256$

   and $R = (A - B)\ /\ (A + B)$

   2.2 $\phi = 45°$

   $A_s = 1.5708\ H\ ((A + B)\ C + (A + B + 2H)\ C_1)$

   where C is same as in Section 2.1,

$$C_1 = 1 + R_1^2 / 4 + R_2^4 / 64 + R_2^6 / 256$$

$$R_1 = (A - B) / (A + B + 2H)$$

2.3 $\emptyset = 65°$

$$A_s = 1.5708H\ ((A + B)\ C + (A + B + 4.289H)\ C_2)$$

where C is same as in Section 2.1

$$C_2 = 1 + R_2^2 / 4 + R_2^4 / 64 + R_2^6 / 256$$

$$R_2 = (A - B) / (A + B + 4.289H)$$

P_w and P_t are computed as in Section 1. of the Appendix.

3. Circular-Rectangular Composite Tire Print of Length - L (See Figs. 1 and 3)

$$A_c = 2.125\ L^2$$

3.1 $\emptyset = 0°$

$$A_s = 0.5227\ L\ H$$

3.2 $\emptyset = 45°$

$$A_s = (2.685L + 3.1416H)\ H$$

3.3 $\emptyset = 65°$

$$A_s = (2.685L + 6.7371H)\ H$$

P_w and P_t are computed as in Section 1. of the Appendix.

5. TABLES

TABLE 1

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 2500 PSI.

TIRE PRINT L/W(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	16(816)	17(884)	19(952)	20(1020)	21(1088)	23(1156)
5/ 5 (2)	20(816)	22(884)	24(952)	25(1020)	27(1088)	29(1156)
5/ 5 (3)	35(1795)	40(2033)	45(2285)	50(2550)	56(2829)	61(3121)
5/ 5 (4)	45(1795)	51(2033)	57(2285)	64(2550)	71(2829)	78(3121)
5/ 5 (5)	57(2916)	66(3348)	75(3810)	84(4301)	95(4821)	105(5370)
5/ 5 (6)	73(2915)	84(3348)	95(3810)	108(4300)	121(4820)	134(5369)
10/10 (1)	32(408)	35(442)	37(476)	40(510)	43(544)	45(578)
10/10 (2)	41(408)	44(442)	48(476)	51(510)	54(544)	58(578)
10/10 (3)	51(653)	57(729)	64(809)	70(892)	77(979)	84(1069)
10/10 (4)	65(653)	73(729)	81(809)	89(892)	98(979)	107(1069)
10/10 (5)	73(933)	83(1058)	94(1191)	104(1330)	116(1477)	128(1632)
10/10 (6)	93(933)	106(1058)	119(1190)	133(1330)	148(1477)	163(1631)
20/20 (1)	64(204)	69(221)	75(238)	80(255)	85(272)	91(289)
20/20 (2)	82(204)	88(221)	95(238)	102(255)	109(272)	116(289)
20/20 (3)	83(265)	92(293)	101(321)	110(351)	120(381)	129(412)
20/20 (4)	106(265)	117(293)	129(321)	140(351)	152(381)	165(412)
20/20 (5)	105(335)	118(375)	131(417)	145(460)	159(505)	174(552)
20/20 (6)	134(335)	150(375)	167(417)	184(460)	202(505)	221(552)
5/20 (1)	44(557)	47(603)	51(650)	55(696)	58(743)	62(789)
5/20 (2)	51(510)	55(552)	59(595)	64(638)	68(680)	72(722)
5/20 (3)	62(790)	69(878)	76(968)	83(1062)	91(1160)	99(1261)
5/20 (4)	75(755)	84(840)	93(928)	102(1020)	112(1115)	121(1214)
5/20 (5)	84(1066)	94(1202)	106(1345)	117(1495)	130(1653)	143(1818)
5/20 (6)	103(1035)	117(1168)	131(1309)	146(1458)	161(1613)	178(1776)
5/40 (1)	83(531)	90(576)	97(620)	104(664)	111(709)	118(753)
5/40 (2)	92(459)	99(497)	107(535)	115(574)	122(612)	130(650)
5/40 (3)	101(641)	111(704)	121(770)	131(837)	142(905)	153(976)
5/40 (4)	116(581)	128(641)	140(702)	153(765)	166(830)	179(896)
5/40 (5)	122(774)	135(861)	150(952)	164(1047)	180(1145)	196(1247)
5/40 (6)	144(721)	161(805)	179(893)	197(984)	216(1079)	235(1177)
10/20 (1)	49(315)	54(341)	58(367)	62(393)	66(419)	70(446)
10/20 (2)	61(306)	66(331)	71(357)	76(382)	82(408)	87(433)
10/20 (3)	68(435)	76(482)	83(531)	91(582)	100(634)	108(688)
10/20 (4)	86(428)	95(475)	105(524)	115(574)	125(626)	136(679)
10/20 (5)	90(574)	101(646)	113(721)	126(800)	139(882)	152(968)
10/20 (6)	114(568)	128(639)	143(714)	159(793)	175(875)	192(960)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 2

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 3000 PSI.

TIRE PRINT L/W (IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	18(894)	19(968)	20(1043)	22(1117)	23(1192)	25(1266)
5/ 5 (2)	22(894)	24(968)	26(1043)	28(1117)	30(1192)	32(1266)
5/ 5 (3)	39(1967)	44(2227)	49(2503)	55(2793)	61(3099)	67(3419)
5/ 5 (4)	49(1967)	56(2227)	63(2503)	70(2793)	77(3099)	85(3419)
5/ 5 (5)	63(3194)	72(3668)	82(4174)	93(4712)	104(5281)	116(5883)
5/ 5 (6)	80(3194)	92(3667)	104(4173)	118(4711)	132(5280)	147(5882)
10/10 (1)	35(447)	38(484)	41(521)	44(559)	47(596)	50(633)
10/10 (2)	45(447)	48(484)	52(521)	56(559)	60(596)	63(633)
10/10 (3)	56(715)	63(799)	70(886)	77(978)	84(1073)	92(1171)
10/10 (4)	72(715)	80(799)	89(886)	98(978)	107(1073)	117(1171)
10/10 (5)	80(1022)	91(1159)	102(1304)	114(1457)	127(1618)	140(1787)
10/10 (6)	102(1022)	116(1159)	130(1304)	146(1457)	162(1618)	179(1787)
20/20 (1)	70(223)	76(242)	82(261)	88(279)	94(298)	99(317)
20/20 (2)	89(223)	97(242)	104(261)	112(279)	119(298)	127(317)
20/20 (3)	91(291)	101(321)	111(352)	121(384)	131(417)	142(451)
20/20 (4)	116(291)	128(321)	141(352)	154(384)	167(417)	180(451)
20/20 (5)	115(367)	129(411)	143(456)	158(504)	174(554)	190(605)
20/20 (6)	147(367)	164(411)	183(456)	202(504)	221(553)	242(605)
5/20 (1)	48(610)	52(661)	56(712)	60(763)	64(814)	68(864)
5/20 (2)	56(559)	61(605)	65(652)	70(698)	74(745)	79(791)
5/20 (3)	68(866)	75(961)	83(1061)	91(1164)	100(1271)	108(1381)
5/20 (4)	83(827)	92(920)	102(1017)	112(1117)	122(1222)	133(1330)
5/20 (5)	92(1168)	103(1317)	116(1473)	129(1638)	142(1811)	156(1991)
5/20 (6)	113(1134)	128(1280)	143(1434)	160(1597)	177(1767)	195(1945)
5/40 (1)	91(582)	99(631)	107(679)	114(728)	122(776)	130(825)
5/40 (2)	101(503)	109(545)	117(587)	126(629)	134(670)	142(712)
5/40 (3)	110(702)	121(772)	132(843)	144(917)	156(992)	168(1069)
5/40 (4)	127(637)	140(702)	154(769)	168(838)	182(909)	196(981)
5/40 (5)	133(848)	148(944)	164(1043)	180(1147)	197(1255)	215(1366)
5/40 (6)	158(790)	176(882)	196(978)	216(1078)	236(1181)	258(1289)
10/20 (1)	54(345)	59(373)	63(402)	68(431)	72(459)	77(488)
10/20 (2)	67(335)	73(363)	78(391)	84(419)	89(447)	95(475)
10/20 (3)	75(477)	83(528)	91(582)	100(637)	109(695)	118(754)
10/20 (4)	94(469)	104(521)	115(574)	126(629)	137(685)	149(744)
10/20 (5)	99(629)	111(707)	124(790)	138(876)	152(966)	167(1061)
10/20 (6)	125(623)	140(701)	156(782)	174(868)	192(958)	210(1052)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 3

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 3500 PSI.

TIRE PRINT L/W (IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	19(966)	21(1046)	22(1126)	24(1207)	25(1287)	27(1368)
5/ 5 (2)	24(966)	26(1046)	28(1126)	30(1207)	32(1287)	34(1368)
5/ 5 (3)	42(2124)	47(2406)	53(2703)	59(3017)	66(3347)	73(3693)
5/ 5 (4)	53(2124)	60(2406)	68(2703)	75(3017)	84(3347)	92(3693)
5/ 5 (5)	68(3450)	78(3962)	89(4508)	100(5089)	112(5704)	125(6354)
5/ 5 (6)	86(3450)	99(3961)	113(4507)	127(5088)	143(5703)	159(6353)
10/10 (1)	38(483)	41(523)	44(563)	47(603)	51(644)	54(684)
10/10 (2)	48(483)	52(523)	56(563)	60(603)	64(644)	68(684)
10/10 (3)	61(772)	68(863)	75(957)	83(1056)	91(1159)	99(1255)
10/10 (4)	77(772)	86(863)	96(957)	106(1056)	116(1159)	127(1265)
10/10 (5)	87(1104)	98(1252)	111(1409)	124(1574)	137(1748)	152(1931)
10/10 (6)	110(1104)	125(1252)	141(1408)	157(1574)	175(1748)	193(1930)
20/20 (1)	76(241)	82(261)	88(282)	95(302)	101(322)	107(342)
20/20 (2)	97(241)	105(261)	113(282)	121(302)	129(322)	137(342)
20/20 (3)	99(314)	109(346)	119(380)	130(415)	142(451)	153(487)
20/20 (4)	126(314)	139(346)	152(380)	166(415)	180(451)	195(487)
20/20 (5)	125(397)	139(444)	155(493)	171(544)	188(598)	205(654)
20/20 (6)	159(397)	177(444)	197(493)	218(544)	239(598)	261(654)
5/20 (1)	52(659)	56(714)	60(769)	65(824)	69(879)	73(934)
5/20 (2)	60(603)	65(654)	70(704)	75(754)	80(805)	85(855)
5/20 (3)	73(935)	82(1038)	90(1146)	99(1257)	108(1373)	117(1492)
5/20 (4)	89(893)	99(994)	110(1098)	121(1207)	132(1320)	144(1436)
5/20 (5)	99(1261)	112(1422)	125(1591)	139(1769)	154(1956)	169(2151)
5/20 (6)	122(1224)	138(1383)	155(1549)	172(1725)	191(1909)	210(2101)
5/40 (1)	99(629)	107(681)	115(734)	123(786)	132(838)	140(891)
5/40 (2)	109(543)	118(588)	127(634)	136(679)	145(724)	154(769)
5/40 (3)	119(758)	131(833)	143(911)	156(990)	168(1071)	181(1154)
5/40 (4)	138(688)	152(758)	166(831)	181(905)	196(982)	212(1060)
5/40 (5)	144(916)	160(1019)	177(1127)	195(1239)	213(1355)	232(1476)
5/40 (6)	171(854)	191(953)	211(1056)	233(1164)	255(1276)	279(1393)
10/20 (1)	58(372)	63(403)	68(434)	73(465)	78(496)	83(527)
10/20 (2)	72(362)	78(392)	84(422)	91(453)	97(483)	103(513)
10/20 (3)	81(515)	90(571)	99(628)	108(688)	118(750)	128(814)
10/20 (4)	101(507)	112(562)	124(620)	136(679)	148(740)	161(804)
10/20 (5)	107(680)	120(764)	134(853)	149(946)	164(1044)	180(1145)
10/20 (5)	135(673)	151(757)	169(845)	188(938)	207(1035)	227(1136)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 4

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 4000 PSI.

TIRE PRINT L/W(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	20(1032)	22(1118)	24(1204)	25(1290)	27(1376)	29(1462)
5/ 5 (2)	26(1032)	28(1118)	30(1204)	32(1290)	34(1376)	37(1462)
5/ 5 (3)	45(2271)	50(2572)	57(2890)	63(3226)	70(3578)	78(3948)
5/ 5 (4)	57(2271)	64(2572)	72(2890)	81(3226)	89(3578)	99(3948)
5/ 5 (5)	72(3688)	83(4236)	95(4820)	107(5440)	120(6098)	133(6793)
5/ 5 (6)	92(3688)	106(4235)	120(4819)	136(5440)	152(6097)	170(6792)
10/10 (1)	41(516)	44(559)	47(602)	51(645)	54(688)	57(731)
10/10 (2)	52(516)	56(559)	60(602)	65(645)	69(688)	73(731)
10/10 (3)	65(826)	72(922)	80(1024)	89(1129)	97(1239)	106(1353)
10/10 (4)	83(826)	92(922)	102(1024)	113(1129)	124(1239)	135(1353)
10/10 (5)	93(1180)	105(1338)	118(1506)	132(1683)	147(1869)	162(2064)
10/10 (6)	118(1180)	134(1338)	151(1506)	168(1682)	187(1868)	206(2064)
20/20 (1)	81(258)	88(280)	95(301)	101(323)	108(344)	115(366)
20/20 (2)	103(258)	112(280)	120(301)	129(323)	138(344)	146(366)
20/20 (3)	105(335)	116(370)	128(406)	139(444)	151(482)	164(521)
20/20 (4)	134(335)	148(370)	163(406)	177(444)	193(482)	208(521)
20/20 (5)	133(424)	149(474)	166(527)	183(582)	201(639)	220(699)
20/20 (6)	170(424)	190(474)	211(527)	233(582)	256(639)	279(699)
5/20 (1)	55(705)	60(763)	65(822)	69(881)	74(939)	78(998)
5/20 (2)	65(645)	70(699)	75(753)	81(806)	86(860)	91(914)
5/20 (3)	78(999)	87(1110)	96(1225)	106(1344)	115(1467)	125(1595)
5/20 (4)	95(955)	106(1062)	117(1174)	129(1290)	141(1411)	154(1535)
5/20 (5)	106(1348)	119(1520)	134(1701)	149(1891)	164(2091)	181(2299)
5/20 (6)	131(1309)	148(1478)	166(1656)	184(1844)	204(2040)	225(2246)
5/40 (1)	106(672)	114(728)	123(784)	132(840)	141(896)	150(952)
5/40 (2)	116(581)	126(629)	135(677)	145(726)	155(774)	165(823)
5/40 (3)	127(810)	140(891)	153(974)	166(1058)	180(1145)	194(1234)
5/40 (4)	147(735)	162(811)	178(888)	194(968)	210(1049)	227(1133)
5/40 (5)	154(979)	171(1090)	189(1205)	208(1325)	228(1449)	248(1578)
5/40 (6)	183(913)	204(1019)	226(1129)	249(1244)	273(1364)	298(1489)
10/20 (1)	63(398)	68(431)	73(464)	78(497)	83(531)	89(564)
10/20 (2)	77(387)	84(419)	90(452)	97(484)	103(516)	110(548)
10/20 (3)	86(550)	96(610)	106(672)	116(736)	126(802)	137(870)
10/20 (4)	108(542)	120(601)	132(662)	145(726)	158(791)	172(859)
10/20 (5)	114(726)	128(817)	143(912)	159(1012)	175(1116)	192(1225)
10/20 (6)	144(719)	162(809)	181(903)	200(1002)	221(1106)	243(1215)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 5

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 4500 PSI.

TIRE PRINT	SLAB THICKNESS (IN IN.)					
L/W(IN.)	6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	21(1095)	23(1186)	25(1277)	27(1368)	29(1460)	30(1551)
5/ 5 (2)	27(1095)	30(1186)	32(1277)	34(1368)	36(1460)	39(1551)
5/ 5 (3)	47(2409)	54(2728)	60(3065)	67(3421)	75(3795)	82(4188)
5/ 5 (4)	60(2409)	68(2728)	77(3065)	86(3421)	95(3795)	105(4188)
5/ 5 (5)	77(3912)	88(4492)	100(5112)	113(5771)	127(6468)	141(7205)
5/ 5 (6)	98(3911)	112(4492)	128(5111)	144(5769)	162(6467)	180(7204)
10/10 (1)	43(547)	47(593)	50(639)	54(684)	57(730)	61(775)
10/10 (2)	55(547)	59(593)	64(639)	68(684)	73(730)	78(775)
10/10 (3)	69(876)	77(978)	85(1086)	94(1197)	103(1314)	113(1435)
10/10 (4)	88(876)	98(978)	109(1086)	120(1197)	131(1314)	143(1435)
10/10 (5)	98(1252)	111(1420)	125(1597)	140(1785)	156(1982)	172(2189)
10/10 (6)	125(1252)	142(1419)	160(1597)	178(1784)	198(1982)	219(2189)
20/20 (1)	86(274)	93(297)	100(319)	107(342)	115(365)	122(388)
20/20 (2)	109(274)	119(297)	128(319)	137(342)	146(365)	155(388)
20/20 (3)	112(356)	123(393)	135(431)	148(470)	161(511)	174(553)
20/20 (4)	142(356)	157(393)	172(431)	188(470)	204(511)	221(553)
20/20 (5)	141(450)	158(503)	176(559)	194(617)	213(678)	233(741)
20/20 (6)	180(450)	201(503)	224(559)	247(617)	271(678)	296(741)
5/20 (1)	59(747)	64(810)	68(872)	73(934)	78(996)	83(1059)
5/20 (2)	68(684)	74(741)	80(798)	86(855)	91(912)	97(969)
5/20 (3)	83(1060)	92(1177)	102(1299)	112(1425)	122(1556)	133(1692)
5/20 (4)	101(1013)	113(1127)	125(1245)	137(1368)	150(1496)	163(1628)
5/20 (5)	112(1430)	127(1612)	142(1804)	158(2006)	174(2217)	192(2439)
5/20 (6)	139(1388)	157(1568)	176(1757)	196(1956)	216(2164)	238(2383)
5/40 (1)	112(713)	121(772)	131(832)	140(891)	149(951)	159(1010)
5/40 (2)	123(616)	133(667)	144(718)	154(770)	164(821)	174(872)
5/40 (3)	135(860)	148(945)	162(1033)	176(1123)	191(1215)	206(1309)
5/40 (4)	156(780)	172(860)	188(942)	205(1026)	223(1113)	240(1202)
5/40 (5)	163(1038)	182(1156)	201(1278)	221(1405)	241(1537)	263(1673)
5/40 (6)	194(968)	216(1080)	240(1198)	264(1320)	289(1447)	316(1579)
10/20 (1)	66(422)	72(457)	77(492)	83(528)	88(563)	94(598)
10/20 (2)	82(411)	89(445)	96(479)	103(513)	109(547)	116(582)
10/20 (3)	92(584)	102(647)	112(713)	123(781)	134(851)	145(923)
10/20 (4)	115(575)	127(637)	140(702)	154(770)	168(839)	182(911)
10/20 (5)	121(771)	136(866)	152(967)	169(1073)	186(1183)	204(1299)
10/20 (6)	153(763)	172(858)	192(958)	213(1063)	235(1173)	258(1288)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 6

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 5000 PSI.

TIRE PRINT L/W (IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	23(1154)	25(1250)	26(1346)	28(1442)	30(1539)	32(1635)
5/ 5 (2)	29(1154)	31(1250)	34(1346)	36(1442)	38(1539)	41(1635)
5/ 5 (3)	50(2539)	56(2875)	63(3231)	71(3606)	79(4001)	87(4414)
5/ 5 (4)	63(2539)	72(2875)	81(3231)	90(3606)	100(4001)	110(4414)
5/ 5 (5)	81(4124)	93(4735)	106(5388)	119(6083)	134(6818)	149(7595)
5/ 5 (6)	103(4123)	118(4735)	135(5387)	152(6082)	170(6817)	190(7593)
10/10 (1)	45(577)	49(625)	53(673)	57(721)	60(769)	64(817)
10/10 (2)	58(577)	63(625)	67(673)	72(721)	77(769)	82(817)
10/10 (3)	73(923)	81(1031)	90(1144)	99(1262)	109(1385)	119(1512)
10/10 (4)	92(923)	103(1031)	114(1144)	126(1262)	138(1385)	151(1512)
10/10 (5)	104(1319)	118(1496)	132(1684)	148(1881)	164(2089)	181(2307)
10/10 (6)	132(1319)	150(1496)	168(1683)	188(1881)	209(2089)	231(2307)
20/20 (1)	91(288)	98(313)	106(337)	113(361)	121(385)	128(409)
20/20 (2)	115(288)	125(313)	135(337)	144(361)	154(385)	163(409)
20/20 (3)	118(375)	130(414)	143(454)	156(496)	169(539)	183(582)
20/20 (4)	150(375)	166(414)	182(454)	198(496)	215(539)	233(582)
20/20 (5)	149(474)	167(530)	185(589)	204(651)	225(715)	245(781)
20/20 (6)	190(474)	212(530)	236(589)	260(651)	286(715)	312(781)
5/20 (1)	62(788)	67(853)	72(919)	77(985)	82(1050)	88(1116)
5/20 (2)	72(721)	78(781)	84(841)	90(902)	96(962)	102(1022)
5/20 (3)	88(1117)	97(1241)	108(1369)	118(1503)	129(1641)	140(1783)
5/20 (4)	107(1067)	119(1188)	131(1313)	144(1442)	158(1577)	172(1717)
5/20 (5)	118(1508)	133(1700)	149(1902)	166(2115)	184(2337)	202(2571)
5/20 (6)	146(1464)	165(1652)	185(1852)	206(2061)	228(2281)	251(2511)
5/40 (1)	118(752)	128(814)	138(877)	148(939)	157(1002)	167(1065)
5/40 (2)	130(649)	141(703)	151(757)	162(811)	173(865)	184(920)
5/40 (3)	142(906)	156(996)	171(1089)	186(1183)	201(1280)	217(1380)
5/40 (4)	164(822)	181(906)	199(993)	216(1082)	235(1173)	253(1267)
5/40 (5)	172(1095)	191(1218)	212(1347)	233(1481)	254(1620)	277(1764)
5/40 (6)	204(1020)	228(1139)	252(1262)	278(1391)	305(1525)	333(1664)
10/20 (1)	70(445)	76(482)	82(519)	87(556)	93(593)	99(630)
10/20 (2)	87(433)	94(469)	101(505)	108(541)	115(577)	123(613)
10/20 (3)	97(615)	107(682)	118(751)	129(823)	141(897)	153(973)
10/20 (4)	121(606)	134(672)	148(740)	162(811)	177(885)	192(960)
10/20 (5)	128(812)	143(913)	160(1020)	178(1131)	196(1247)	215(1369)
10/20 (6)	161(804)	181(904)	202(1010)	224(1121)	247(1237)	272(1358)

NOTES= (1) ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3) ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6) RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 7

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH .
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 5500 PSI.

TIRE PRINT	SLAB THICKNESS (IN IN.)					
L/W(IN.)	6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	24(1210)	26(1311)	28(1412)	30(1513)	32(1614)	34(1715)
5/ 5 (2)	30(1210)	33(1311)	35(1412)	38(1513)	40(1614)	43(1715)
5/ 5 (3)	52(2663)	59(3016)	67(3389)	74(3782)	82(4196)	91(4629)
5/ 5 (4)	67(2663)	75(3016)	85(3389)	95(3782)	105(4196)	116(4629)
5/ 5 (5)	85(4325)	98(4967)	111(5651)	125(6380)	140(7151)	156(7966)
5/ 5 (6)	108(4324)	124(4966)	141(5650)	159(6378)	179(7150)	199(7964)
10/10 (1)	48(605)	51(656)	55(706)	59(756)	63(807)	67(857)
10/10 (2)	61(605)	66(656)	71(706)	76(756)	81(807)	86(857)
10/10 (3)	76(968)	85(1082)	94(1200)	104(1324)	114(1452)	125(1586)
10/10 (4)	97(968)	108(1082)	120(1200)	132(1324)	145(1452)	159(1586)
10/10 (5)	109(1384)	123(1569)	139(1766)	155(1973)	172(2191)	190(2420)
10/10 (6)	138(1384)	157(1569)	177(1766)	197(1973)	219(2191)	242(2420)
20/20 (1)	95(303)	103(328)	111(353)	119(378)	127(403)	135(429)
20/20 (2)	121(303)	131(328)	141(353)	151(378)	161(403)	171(429)
20/20 (3)	124(393)	136(434)	150(477)	163(520)	177(565)	192(611)
20/20 (4)	157(393)	174(434)	191(477)	208(520)	228(565)	244(611)
20/20 (5)	156(497)	175(556)	194(618)	214(682)	235(750)	257(819)
20/20 (6)	199(497)	222(556)	247(618)	273(682)	300(749)	328(819)
5/20 (1)	65(826)	70(895)	76(964)	81(1033)	87(1102)	92(1170)
5/20 (2)	76(756)	82(819)	88(883)	95(946)	101(1009)	107(1072)
5/20 (3)	92(1172)	102(1302)	113(1436)	124(1576)	135(1721)	147(1870)
5/20 (4)	112(1120)	125(1246)	138(1377)	151(1513)	165(1654)	180(1800)
5/20 (5)	124(1581)	140(1783)	157(1995)	174(2218)	193(2452)	212(2696)
5/20 (6)	153(1535)	173(1733)	194(1942)	216(2162)	239(2393)	263(2634)
5/40 (1)	124(788)	134(854)	144(920)	155(985)	165(1051)	175(1117)
5/40 (2)	136(681)	148(738)	159(794)	170(851)	182(908)	193(954)
5/40 (3)	149(950)	164(1045)	179(1142)	195(1241)	211(1343)	227(1447)
5/40 (4)	172(862)	190(951)	208(1041)	227(1135)	246(1230)	265(1329)
5/40 (5)	180(1148)	201(1278)	222(1413)	244(1553)	267(1699)	291(1850)
5/40 (6)	214(1070)	239(1194)	265(1324)	292(1459)	320(1600)	349(1746)
10/20 (1)	73(467)	79(505)	86(544)	92(583)	98(622)	104(661)
10/20 (2)	91(454)	98(492)	106(530)	113(567)	121(605)	129(643)
10/20 (3)	101(645)	112(715)	124(788)	136(863)	148(940)	160(1021)
10/20 (4)	127(635)	141(705)	155(777)	170(851)	186(928)	201(1007)
10/20 (5)	134(852)	150(958)	168(1069)	186(1186)	206(1308)	225(1436)
10/20 (6)	169(843)	190(949)	212(1059)	235(1176)	259(1297)	285(1424)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 8

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
CONCRETE CYLINDER STRENGTH= 6000 PSI.

TIRE PRINT	SLAB THICKNESS (IN IN.)					
L/W(IN.)	6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	25(1264)	27(1369)	29(1475)	31(1580)	33(1686)	35(1791)
5/ 5 (2)	32(1264)	34(1369)	37(1475)	40(1580)	42(1686)	45(1791)
5/ 5 (3)	55(2781)	62(3150)	69(3540)	78(3950)	86(4382)	95(4835)
5/ 5 (4)	70(2781)	79(3150)	88(3540)	99(3950)	110(4382)	121(4835)
5/ 5 (5)	89(4517)	102(5187)	116(5903)	131(6663)	147(7469)	163(8320)
5/ 5 (6)	113(4517)	130(5187)	148(5902)	167(6662)	187(7468)	208(8318)
10/10 (1)	50(632)	54(685)	58(737)	62(790)	66(843)	70(895)
10/10 (2)	63(632)	68(685)	74(737)	79(790)	84(843)	90(895)
10/10 (3)	79(1011)	89(1130)	98(1254)	109(1383)	119(1517)	130(1657)
10/10 (4)	101(1011)	113(1130)	125(1254)	138(1383)	152(1517)	166(1657)
10/10 (5)	114(1445)	129(1639)	145(1844)	162(2061)	180(2289)	199(2528)
10/10 (6)	145(1445)	164(1639)	184(1844)	206(2061)	229(2288)	253(2527)
20/20 (1)	99(316)	108(342)	116(369)	124(395)	132(421)	141(448)
20/20 (2)	126(316)	137(342)	147(369)	158(395)	169(421)	179(448)
20/20 (3)	129(411)	143(454)	156(498)	171(543)	185(590)	200(638)
20/20 (4)	164(411)	181(454)	199(498)	217(543)	236(590)	255(638)
20/20 (5)	163(519)	183(581)	203(645)	224(713)	246(783)	269(856)
20/20 (6)	208(519)	232(581)	258(645)	285(713)	313(783)	342(856)
5/20 (1)	68(863)	73(935)	79(1007)	85(1079)	90(1151)	96(1222)
5/20 (2)	79(790)	86(856)	92(922)	99(988)	105(1053)	112(1119)
5/20 (3)	96(1224)	107(1359)	118(1500)	129(1646)	141(1797)	153(1953)
5/20 (4)	117(1169)	130(1301)	144(1438)	158(1580)	173(1728)	188(1880)
5/20 (5)	130(1651)	146(1862)	164(2083)	182(2316)	201(2561)	221(2816)
5/20 (6)	160(1603)	181(1810)	203(2028)	226(2258)	250(2499)	275(2751)
5/40 (1)	129(823)	140(892)	151(961)	162(1029)	172(1098)	183(1166)
5/40 (2)	142(711)	154(770)	166(830)	178(889)	190(948)	201(1007)
5/40 (3)	156(992)	171(1091)	187(1192)	204(1296)	220(1402)	237(1511)
5/40 (4)	180(901)	199(993)	218(1088)	237(1185)	257(1285)	278(1388)
5/40 (5)	188(1199)	210(1335)	232(1476)	255(1622)	279(1774)	304(1932)
5/40 (6)	224(1118)	249(1247)	277(1383)	305(1524)	334(1671)	365(1823)
10/20 (1)	77(487)	83(528)	89(569)	96(609)	102(650)	108(690)
10/20 (2)	95(474)	103(514)	111(553)	119(593)	126(632)	134(672)
10/20 (3)	106(674)	117(747)	129(823)	142(901)	154(982)	167(1066)
10/20 (4)	133(664)	147(736)	162(811)	178(889)	194(969)	210(1052)
10/20 (5)	140(890)	157(1000)	175(1117)	195(1239)	215(1367)	236(1500)
10/20 (6)	176(881)	198(991)	221(1106)	245(1228)	271(1355)	297(1487)

NOTES= (1)ELLIPTIC CYLINDRICAL PUNCH, (2) RECTANGULAR CYLINDRICAL PUNCH (3)ELLIPTIC CONE WITH 45 DEGREE SLOPE, (4) RECTANGULAR PRISM WITH 45 DEGREE SLOPE, (5) ELLIPTIC CONE WITH 65 DEGREE SLOPE, (6)RECTANGULAR CONE WITH 65 DEGREE SLOPE

TABLE 9

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 2500 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	14(1048)	15(1135)	16(1222)	17(1310)	18(1397)	19(1484)
5	(2)	33(2519)	37(2862)	42(3225)	47(3609)	52(4013)	58(4437)
5	(3)	55(4203)	63(4838)	72(5517)	82(6239)	92(7006)	102(7816)
10	(1)	27(524)	30(568)	32(611)	34(655)	37(699)	39(742)
10	(2)	47(892)	52(999)	58(1112)	64(1230)	71(1352)	77(1480)
10	(3)	69(1313)	78(1493)	88(1685)	99(1887)	110(2101)	122(2325)
15	(1)	41(349)	45(378)	48(407)	51(437)	55(466)	58(495)
15	(2)	60(513)	67(570)	74(630)	81(692)	89(756)	97(823)
15	(3)	82(700)	93(790)	104(885)	116(984)	128(1089)	141(1198)
20	(1)	55(262)	59(284)	64(306)	68(327)	73(349)	78(371)
20	(2)	74(354)	82(392)	90(431)	99(471)	107(513)	116(556)
20	(3)	96(459)	108(515)	120(574)	133(636)	146(700)	160(767)

TABLE 10

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 3000 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	15(1148)	16(1243)	18(1339)	19(1435)	20(1530)	21(1626)
5	(2)	36(2759)	41(3135)	46(3533)	52(3953)	57(4396)	64(4860)
5	(3)	60(4604)	69(5300)	79(6043)	89(6835)	100(7675)	112(8562)
10	(1)	30(574)	33(622)	35(670)	38(717)	40(765)	43(813)
10	(2)	51(977)	57(1095)	64(1218)	70(1347)	77(1481)	85(1622)
10	(3)	75(1438)	86(1636)	96(1846)	108(2067)	120(2301)	133(2547)
15	(1)	45(383)	49(414)	53(446)	56(478)	60(510)	64(542)
15	(2)	66(562)	73(625)	81(690)	89(758)	97(828)	106(901)
15	(3)	90(767)	102(865)	114(969)	127(1078)	140(1193)	154(1313)
20	(1)	60(287)	65(311)	70(335)	75(359)	80(383)	85(407)
20	(2)	81(388)	90(429)	99(472)	108(516)	117(562)	127(609)
20	(3)	105(503)	118(564)	131(629)	146(696)	160(767)	176(840)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3) 65 DEGREE CONE

TABLE 11

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 3500 PSI.

TIRE PRINT		SLAB THICKNESS (IN IN.)					
L (IN.)		6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	16(1240)	18(1343)	19(1446)	20(1550)	22(1653)	23(1756)
5	(2)	39(2981)	44(3386)	50(3816)	56(4270)	62(4748)	69(5250)
5	(3)	65(4973)	75(5724)	85(6527)	96(7383)	108(8290)	121(9248)
10	(1)	32(620)	35(672)	38(723)	41(775)	43(827)	46(878)
10	(2)	55(1055)	62(1182)	69(1316)	76(1455)	84(1600)	92(1752)
10	(3)	81(1553)	92(1767)	104(1993)	117(2233)	130(2486)	144(2751)
15	(1)	49(413)	53(448)	57(482)	61(517)	65(551)	69(585)
15	(2)	71(607)	79(675)	88(745)	96(819)	105(895)	115(974)
15	(3)	97(828)	110(934)	123(1047)	137(1165)	152(1288)	167(1418)
20	(1)	65(310)	70(336)	76(362)	81(387)	86(413)	92(439)
20	(2)	88(419)	97(463)	107(510)	117(557)	127(607)	137(657)
20	(3)	114(543)	127(610)	142(679)	157(752)	173(828)	190(907)

TABLE 12

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 4000 PSI.

TIRE PRINT		SLAB THICKNESS (IN IN.)					
L (IN.)		6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	17(1325)	19(1436)	20(1546)	22(1657)	23(1767)	25(1878)
5	(2)	42(3186)	47(3620)	53(4079)	60(4564)	66(5076)	73(5612)
5	(3)	69(5316)	80(6119)	91(6978)	103(7892)	116(8862)	129(9887)
10	(1)	35(663)	38(718)	40(773)	43(828)	46(884)	49(939)
10	(2)	59(1128)	66(1264)	74(1406)	81(1555)	89(1711)	98(1873)
10	(3)	87(1660)	99(1889)	111(2131)	125(2387)	139(2657)	154(2941)
15	(1)	52(442)	56(479)	61(515)	65(552)	69(589)	74(626)
15	(2)	76(649)	85(721)	94(797)	103(875)	113(957)	122(1041)
15	(3)	104(885)	118(999)	132(1119)	146(1245)	162(1377)	178(1516)
20	(1)	69(331)	75(359)	81(387)	87(414)	92(442)	98(469)
20	(2)	94(448)	104(495)	114(545)	125(596)	136(649)	147(703)
20	(3)	121(581)	136(652)	152(726)	168(804)	185(885)	203(970)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3) 65 DEGREE CONE

TABLE 13

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 4500 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	18(1406)	20(1523)	21(1640)	23(1757)	24(1874)	26(1992)
5	(2)	44(3380)	50(3839)	57(4327)	63(4841)	70(5383)	78(5953)
5	(3)	74(5639)	85(6491)	97(7401)	109(8371)	123(9399)	137(*49.)
10	(1)	37(703)	40(761)	43(820)	46(879)	49(937)	52(996)
10	(2)	63(1196)	70(1341)	78(1492)	86(1650)	95(1814)	104(1986)
10	(3)	92(1761)	105(2003)	118(2260)	132(2532)	147(2818)	163(3120)
15	(1)	55(469)	60(508)	64(547)	69(586)	73(625)	78(664)
15	(2)	81(688)	90(765)	99(845)	109(928)	119(1015)	130(1104)
15	(3)	110(939)	125(1060)	140(1187)	155(1321)	172(1461)	189(1608)
20	(1)	73(351)	80(381)	86(410)	92(439)	98(469)	104(498)
20	(2)	99(475)	110(526)	121(578)	132(632)	144(688)	156(745)
20	(3)	129(616)	145(691)	161(770)	178(853)	196(939)	215(1029)

TABLE 14

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 5000 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	19(1482)	21(1605)	23(1729)	24(1852)	26(1976)	27(2099)
5	(2)	47(3562)	53(4047)	60(4561)	67(5103)	74(5675)	82(6275)
5	(3)	78(5944)	89(6842)	102(7802)	115(8824)	129(9908)	144(*05.)
10	(1)	39(741)	42(803)	45(864)	48(926)	52(988)	55(1050)
10	(2)	66(1261)	74(1413)	82(1572)	91(1739)	100(1913)	109(2094)
10	(3)	97(1856)	110(2112)	125(2383)	140(2669)	155(2971)	172(3288)
15	(1)	58(494)	63(535)	68(576)	73(617)	77(659)	82(700)
15	(2)	85(725)	95(806)	105(891)	115(979)	126(1070)	137(1164)
15	(3)	116(990)	131(1117)	147(1251)	164(1392)	181(1540)	199(1695)
20	(1)	77(370)	84(401)	90(432)	97(463)	103(494)	110(525)
20	(2)	105(500)	116(554)	127(609)	139(666)	152(725)	164(786)
20	(3)	135(649)	152(729)	170(812)	188(899)	207(990)	227(1084)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3) 65 DEGREE CONE

TABLE 15

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 5500 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	20(1554)	22(1684)	24(1813)	25(1943)	27(2072)	29(2202)
5	(2)	49(3736)	55(4245)	63(4783)	70(5352)	78(5952)	86(6581)
5	(3)	81(6234)	94(7176)	107(8183)	121(9255)	136(*39.)	152(*59.)
10	(1)	41(777)	44(842)	47(907)	51(971)	54(1036)	58(1101)
10	(2)	69(1323)	77(1482)	86(1649)	95(1824)	105(2006)	115(2196)
10	(3)	102(1947)	116(2215)	131(2499)	146(2799)	163(3116)	180(3449)
15	(1)	61(518)	66(561)	71(604)	76(648)	81(691)	86(734)
15	(2)	89(761)	99(846)	110(934)	121(1026)	132(1122)	144(1221)
15	(3)	122(1038)	138(1171)	154(1312)	172(1460)	190(1615)	209(1777)
20	(1)	81(389)	88(421)	95(453)	102(486)	108(518)	115(550)
20	(2)	110(525)	121(581)	134(639)	146(699)	159(761)	172(824)
20	(3)	142(681)	160(764)	178(851)	197(943)	217(1038)	238(1137)

TABLE 16

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
TIRE PRINT GEOMETRY USED BY J.MOE-P.C.A.
CONCRETE CYLINDER STRENGTH= 6000 PSI.

TIRE PRINT L (IN.)		SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5	(1)	21(1623)	23(1759)	25(1894)	27(2029)	28(2164)	30(2300)
5	(2)	51(3902)	58(4433)	65(4996)	73(5590)	81(6216)	90(6874)
5	(3)	85(6511)	98(7495)	112(8546)	126(9666)	142(*85.)	158(*11.)
10	(1)	42(812)	46(879)	49(947)	53(1015)	57(1082)	60(1150)
10	(2)	72(1381)	81(1548)	90(1722)	100(1905)	110(2095)	120(2293)
10	(3)	106(2034)	121(2313)	136(2610)	153(2924)	170(3254)	188(3602)
15	(1)	64(541)	69(586)	74(631)	80(676)	85(721)	90(767)
15	(2)	93(794)	104(883)	115(976)	126(1072)	138(1172)	150(1275)
15	(3)	128(1084)	144(1224)	161(1370)	179(1525)	198(1687)	218(1856)
20	(1)	85(406)	92(440)	99(473)	106(507)	113(541)	120(575)
20	(2)	115(548)	127(607)	140(667)	153(730)	166(794)	180(861)
20	(3)	149(711)	167(798)	186(889)	206(985)	227(1084)	248(1188)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3) 65 DEGREE CONE

TABLE 17

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 2500 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	50(1991)	54(2176)	59(2360)	64(2545)	68(2730)	73(2914)
5/ 5 (2)	110(4381)	125(5004)	142(5665)	159(6362)	177(7097)	197(7868)
5/ 5 (3)	178(7114)	206(8240)	236(9445)	268(9999)	302(9999)	338(9999)
10/10 (1)	88(884)	98(976)	107(1068)	116(1160)	125(1253)	135(1345)
10/10 (2)	141(1414)	161(1610)	182(1816)	203(2031)	226(2255)	249(2488)
10/10 (3)	202(2020)	234(2336)	267(2671)	303(3027)	340(3402)	380(3796)
20/20 (1)	860(2150)	865(2162)	169(422)	187(468)	206(514)	224(561)
20/20 (2)	1118(2795)	1146(2865)	228(570)	258(644)	288(720)	320(799)
20/20 (3)	1413(3533)	1468(3669)	296(739)	338(845)	382(956)	429(1071)

TABLE 18

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 3000 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	55(2181)	60(2383)	65(2586)	70(2788)	75(2990)	80(3192)
5/ 5 (2)	120(4799)	137(5482)	155(6206)	174(6970)	194(7774)	215(8619)
5/ 5 (3)	195(7793)	226(9027)	259(9999)	294(9999)	331(9999)	371(9999)
10/10 (1)	97(968)	107(1069)	117(1170)	127(1271)	137(1372)	147(1473)
10/10 (2)	155(1549)	176(1764)	199(1989)	222(2225)	247(2470)	273(2726)
10/10 (3)	221(2213)	256(2559)	293(2926)	332(3315)	373(3726)	416(4159)
20/20 (1)	942(2355)	948(2369)	185(462)	205(513)	225(563)	246(614)
20/20 (2)	1225(3062)	1256(3139)	250(624)	282(705)	316(789)	350(875)
20/20 (3)	1548(3870)	1608(4020)	324(809)	370(925)	419(1047)	469(1174)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3)65 DEGREE CONE
ALL PRINTS ARE SQUARE

TABLE 19

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 3500 PSI.

TIRE PRINT	SLAB THICKNESS (IN IN.)					
R/R(IN.)	6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	59(2356)	64(2574)	70(2793)	75(3011)	81(3230)	86(3448)
5/ 5 (2)	130(5183)	148(5921)	168(6703)	188(7528)	210(8397)	233(9310)
5/ 5 (3)	210(8418)	244(9750)	279(9999)	317(9999)	358(9999)	400(9999)
10/10 (1)	105(1045)	115(1155)	126(1264)	137(1373)	148(1482)	159(1592)
10/10 (2)	167(1673)	191(1905)	215(2149)	240(2403)	267(2668)	294(2944)
10/10 (3)	239(2390)	276(2764)	316(3161)	358(3581)	402(4025)	449(4492)
20/20 (1)	1018(2544)	1023(2559)	200(499)	222(554)	243(609)	265(663)
20/20 (2)	1323(3307)	1356(3390)	270(674)	305(762)	341(852)	378(945)
20/20 (3)	1672(4180)	1737(4342)	350(874)	400(999)	452(1131)	507(1268)

TABLE 20

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 4000 PSI.

TIRE PRINT	SLAB THICKNESS (IN IN.)					
R/R(IN.)	6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	63(2519)	69(2752)	75(2986)	80(3219)	86(3453)	92(3686)
5/ 5 (2)	139(5541)	158(6330)	179(7166)	201(8048)	224(8977)	249(9953)
5/ 5 (3)	225(8999)	261(9999)	299(9999)	339(9999)	382(9999)	428(9999)
10/10 (1)	112(1118)	123(1234)	135(1351)	147(1468)	158(1585)	170(1701)
10/10 (2)	179(1788)	204(2037)	230(2297)	257(2569)	285(2852)	315(3148)
10/10 (3)	256(2555)	295(2955)	338(3379)	383(3828)	430(4303)	480(4802)
20/20 (1)	1088(2720)	1094(2735)	214(534)	237(592)	260(651)	284(709)
20/20 (2)	1414(3535)	1450(3624)	288(721)	326(814)	364(911)	404(1010)
20/20 (3)	1788(4469)	1857(4641)	374(935)	427(1068)	483(1209)	542(1355)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3)65 DEGREE CONE
ALL PRINTS ARE SQUARE

TABLE 21

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF FCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 4500 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	67(2671)	73(2919)	79(3167)	85(3414)	92(3662)	98(3910)
5/ 5 (2)	147(5877)	168(6714)	190(7600)	213(8536)	238(9522)	264(9999)
5/ 5 (3)	239(9545)	276(9999)	317(9999)	360(9999)	406(9999)	454(9999)
10/10 (1)	119(1185)	131(1309)	143(1433)	156(1557)	168(1681)	180(1805)
10/10 (2)	190(1897)	216(2160)	244(2436)	272(2725)	303(3025)	334(3339)
10/10 (3)	271(2710)	313(3134)	358(3584)	406(4061)	456(4564)	509(5093)
20/20 (1)	1154(2885)	1161(2901)	227(566)	251(628)	276(690)	301(752)
20/20 (2)	1500(3750)	1538(3844)	306(765)	346(864)	386(966)	429(1072)
20/20 (3)	1896(4740)	1969(4923)	397(991)	453(1133)	513(1282)	575(1437)

TABLE 22

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF FCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 5000 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	70(2816)	77(3077)	83(3338)	90(3599)	97(3860)	103(4121)
5/ 5 (2)	155(6195)	177(7077)	200(8011)	225(8998)	251(9999)	278(9999)
5/ 5 (3)	252(9999)	291(9999)	334(9999)	379(9999)	428(9999)	479(9999)
10/10 (1)	125(1250)	138(1380)	151(1511)	164(1641)	177(1772)	190(1902)
10/10 (2)	200(1999)	228(2277)	257(2568)	287(2872)	319(3189)	352(3519)
10/10 (3)	286(2857)	330(3303)	378(3778)	428(4280)	481(4811)	537(5369)
20/20 (1)	1216(3041)	1223(3058)	239(597)	265(662)	291(727)	317(793)
20/20 (2)	1581(3953)	1621(4052)	322(806)	364(911)	407(1018)	452(1130)
20/20 (3)	1998(4996)	2076(5189)	418(1045)	478(1195)	541(1351)	606(1515)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3)65 DEGREE CONE
ALL PRINTS ARE SQUARE

TABLE 23

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 5500 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	74(2953)	81(3227)	88(3501)	94(3775)	101(4049)	108(4322)
5/ 5 (2)	162(6498)	186(7423)	210(8402)	236(9437)	263(9999)	292(9999)
5/ 5 (3)	264(9999)	306(9999)	350(9999)	398(9999)	448(9999)	502(9999)
10/10 (1)	131(1311)	145(1447)	158(1584)	172(1721)	186(1858)	200(1995)
10/10 (2)	210(2097)	239(2388)	269(2693)	301(3012)	334(3345)	369(3691)
10/10 (3)	300(2997)	346(3465)	396(3962)	449(4489)	505(5045)	563(5631)
20/20 (1)	1276(3189)	1283(3208)	250(626)	278(695)	305(763)	333(831)
20/20 (2)	1658(4146)	1700(4250)	338(845)	382(955)	427(1068)	474(1185)
20/20 (3)	2096(5240)	2177(5442)	438(1096)	501(1253)	567(1417)	636(1589)

TABLE 24

WHEEL LOADS (IN KIPS.) TO INDUCE SHEAR PUNCH
TIRE PRESSURES (IN PSI.) ARE GIVEN IN PARENTHESIS
USING FORMULA 8.9 OF PCA BULLETIN D47
CONCRETE CYLINDER STRENGTH= 6000 PSI.

TIRE PRINT R/R(IN.)	SLAB THICKNESS (IN IN.) 6.0	6.5	7.0	7.5	8.0	8.5
5/ 5 (1)	77(3085)	84(3371)	91(3657)	99(3943)	106(4229)	113(4515)
5/ 5 (2)	170(6786)	194(7753)	219(8776)	246(9857)	275(9999)	305(9999)
5/ 5 (3)	276(9999)	319(9999)	366(9999)	416(9999)	468(9999)	524(9999)
10/10 (1)	137(1369)	151(1512)	165(1655)	180(1798)	194(1941)	208(2084)
10/10 (2)	219(2190)	249(2495)	281(2813)	315(3146)	349(3493)	386(3855)
10/10 (3)	313(3130)	362(3619)	414(4138)	469(4689)	527(5270)	588(5881)
20/20 (1)	1332(3331)	1340(3350)	262(654)	290(725)	319(797)	347(868)
20/20 (2)	1732(4330)	1776(4439)	353(883)	399(997)	446(1116)	495(1237)
20/20 (3)	2189(5473)	2274(5685)	458(1145)	523(1309)	592(1480)	664(1660)

NOTES= (1)CYLINDRICAL PUNCH, (2)45 DEGREE CONE, (3)65 DEGREE CONE
ALL PRINTS ARE SQUARE

6. FIGURES

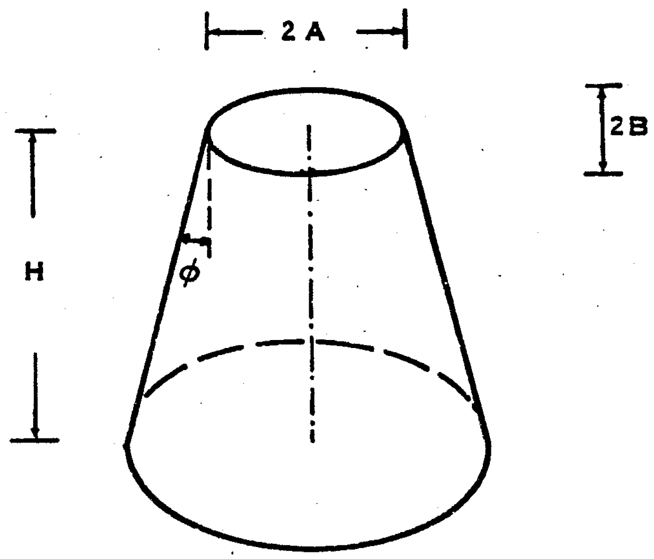

Fig. 1 Shear Cone Model

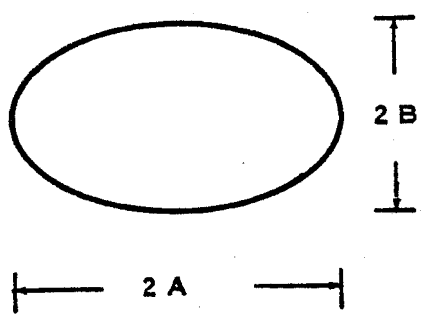

Fig. 2 Elliptical Tire Print

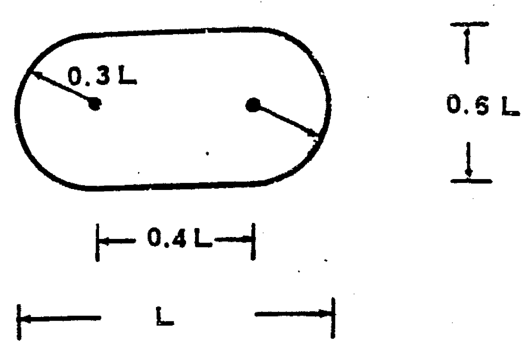

Fig. 3 J. Moe Tire Print Model

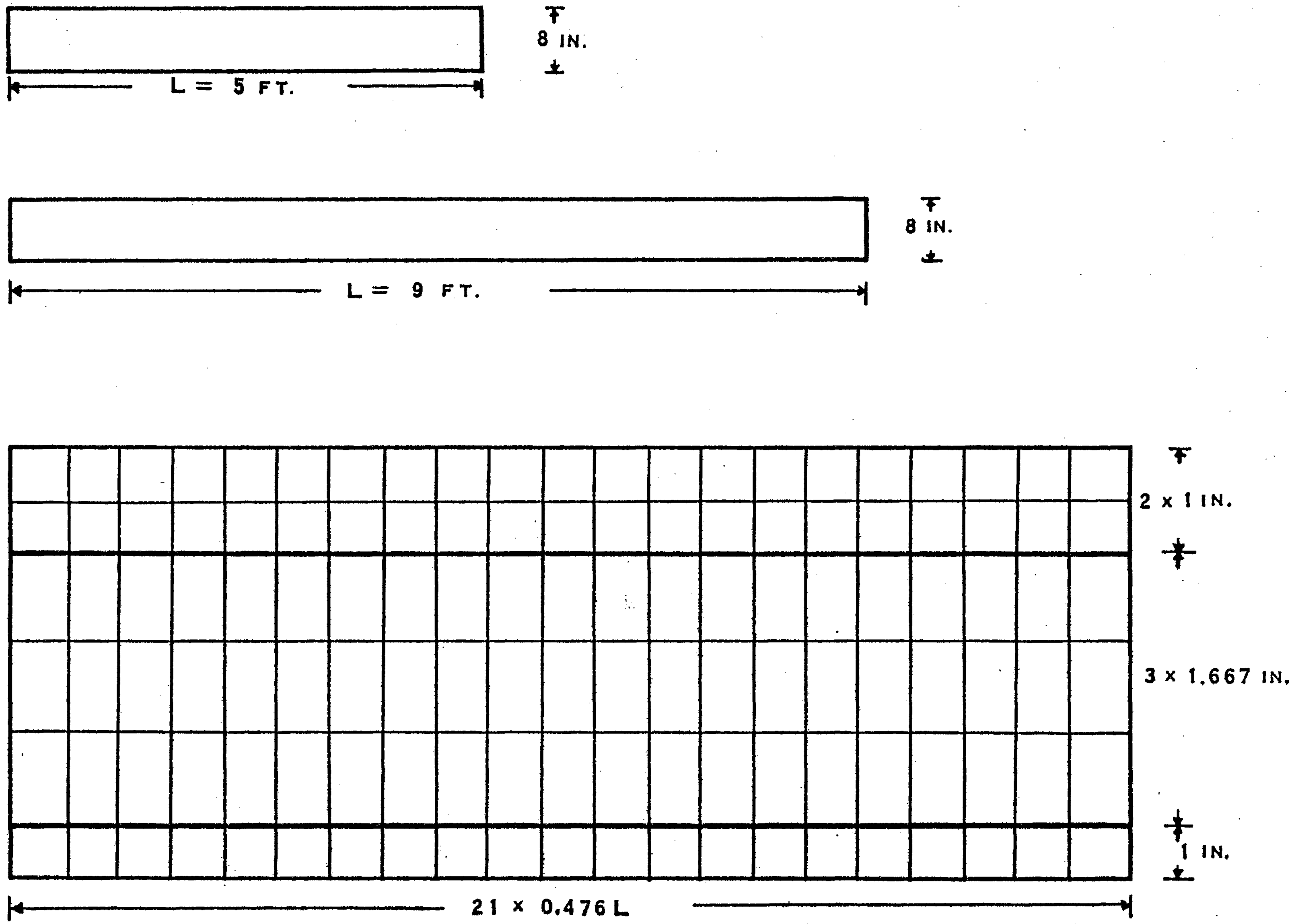

Fig. 4 General Finite Element Model For Various Slab Configurations

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