V–13. New Masonry Codes: The Need for Calibration

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ABSTRACT

Recently several countries have been active in the preparation of new Codes of Practice for masonry construction, and in the United Kingdom BS 5628 : Part 1 : 1978, 'Code of Practice for Structural Use of Masonry' has been published. When reaching a final decision on publication the Committee responsible for preparation of BS 5628 wished to be satisfied that the level of safety achieved by the new Code would be acceptable in the light of present practice and the existing Code, CP 111. Similarly in the preparation of International Proposals the representatives of individual countries are interested in whether the results are acceptable to them nationally.

By designing several buildings and a number of individual walls using a proposed new Code and any previous basis of design, differences become clear. This process, known as calibration, has been adopted in the United Kingdom to compare BS 5628 with the existing Code, CP 111, and to compare the CIB Draft International Recommendations with BS 5628. The scope of the exercises and the more important results are given in this paper. Although in some aspects of design BS 5628 permits larger loads to be carried than does CP 111, the Code Committee considered that adequate levels of safety were being maintained. The CIB Draft Recommendations give results more conservative than both the British Codes in all aspects of design.

Récemment, plusieurs pays se sont activés à la préparation de nouveaux Codes de pratique de construction en maçonnerie, et au Royaume Uni la BS5628: Part 1: 1978, 'Code of Practice for Structural Use of Masonry' (Règles de pratique pour l'emploi de maçonnerie pour l'ossature) a été publiée. Au stade de décider finalement sur la publication, le Comité responsable pour la préparation de la BS5628 désirait être satisfait que le niveau de sécurité atteint par le nouveau Code serait acceptable en vue des pratiques présentes et du Code existant, le CP111. De même dans la préparation des Propositions Internationales, les représentants de pays individuels sont intéressés à savoir si les résultats sont acceptables pour eux-mêmes à l'échelle nationale.

Par l'étude de plusieurs batiments et d'un certain nombre de murs individuels en utilisant le nouveau code proposé et toute base d'étude précédente, les différences devinrent claires. Ce procédé connu sous le nom d'étalonnage ('calibration'), a été adopté au Royaume Uni pour comparer la BS5628 avec le Code existant, le CP111, et pour comparer le projet de Recommandations internationales du CIB avec la BS5628. L'étendue de ces exercises et les résultats les plus importants sont donnés dans le présent document. Bien que pour certains aspects d'études, la BS5628 permet de porter des charges plus grandes que ne le fait le CP 111, le Comité du Code considéra que des niveaux adéquats de sécurité se trouvaient maintenus. Le projet de Recommandations du CIB donne des résultats plus conservateurs que les deux Codes britanniques pour tous les aspects d'étude.

Unlängst waren verschiedene Länder in der Erstellung von neuen praktischen Codes für Mauerwerk Tätig, und in Großbritannien wurde BS 5628: Teil 1: 1978, "Praktischer Code für die Anwendung von Mauerwerk im Bau" veröffentlich. Als sich das für die Erstellung von BS 5628 verantwortliche Komitee für eine Veröffentlichung entschied, wollte es festellen, daß die durch den neuen Code erreichte Sicherheit angesichts der bestehenden Verfahrenspraxis und dem vorhandenen Code CP 111 annehmbar war. Auf gleiche Weise sind während der Vorbereitung von internationalen Vorschlägen die Abgeordneten der verschiedenen Länder darüber interessiert, ob die Ergebnisse national annehmbar sind.

Durch die Konstruktion von verschiedenen Gebäuden und einer Anzahl von einzelnen Wänden unter Anwendung des vorgeschlagenen neuen Codes und vorhandenen Konstruktionsgrundlagen stellten sich die Unterschiede klar heraus. Dieses als Eichung bekannte Verfahren wurde in Großbritannien dazu ausgenutzt, BS 5628 mit dem bestehenden Code CP 111 sowie den Entwurf der CIB internationalen Empfehlungen mit BS 5628 zu vergleichen. Der Umfang dieser Arbeiten und die wichtigeren Ergebnisse werden in diesem Artikel bekanntgegeben. Obgleich mit Hinsicht auf einigen Konstruktionsunterlagen BS 5628 höhere Belastungen als CP 111 erlaubt, denkt das Code-Komitee, daß eine ausreichende Sicherheitsgüte aufrechterhalten wird. Der Entwurf der CIB-Empfehlungen gibt konservativere Resultate in allen Konstruktionsgesichtspunkten als beide britischen Codes.

Recentemente molti paesi sono stati attivi nella preparazione di nuove Norme per costruzioni in muratura e nella Gran Bretagna sono state pubblicate le Norme BS5628 : Parte 1 : 1978, "Norme per l'Uso Strutturale di Muratura." Quando ha raggiunto una decisione finale circa la pubblicazione, il Comitato responsabile per la preparazione delle Norme BS5628 ha voluto accertare che il livello di sicurezza ottenuto con le nuove Norme

sarebbe stato accettabile alla luce della presente esperienza e delle Norme precedenti CP111. Similmente, nella preparazione di Proposte Internazionali, i rappresentanti dei vari paesi sono interessati nell'accettabilità dei risultati nelle loro rispettive nazioni.

Le differenze divengono chiare se si progettano parecchi edifici e vari muri separati usando sia le nuove Norme che tutti i criteri precedenti di progettazione. Questo procedimento, chiamato taratura, è stato adottato in Gran Bretagna per paragonare le nuove Norme BS5628 con le Norme preesistenti CP111, e per paragonare le Raccomandazioni Provvisorie Internazionali CIB con le Norme BS5628. Questo articolo descrive l'estento di questo confronto ed i risultati più importanti che sono stati ottenuti. Sebbene sotto certi aspetti della progettazione le Norme BS5628 permettano sollecitazioni più alte di quanto permesso dalle Norme CP111, il Comitato per le Norme considera che si sia mantenuto un livello adeguato di sicurezza. Le Raccomandazioni Provvisorie CIB danno risultati più conservativi sotto tutti gli aspetti di progettazione ed a confronto di entrambe le Norme britanniche.

INTRODUCTION

The United Kingdom has had a Code of Practice for masonry construction based on design to permissible stress since 1948(1). It was revised in 1964 and was nearing the end of revision again in 1970 when the decision was made to adopt the limit state approach to design to coincide with publication of a new Code of Practice for concrete construction, then being prepared in that way. The change from the permissible stress to the limit state basis proved to be time consuming and the new Code, BS5628: Part 1: 1978, 'Structural Use of Masonry, Part 1, Unreinforced masonry'(2) was published in 1978. In addition to this change of approach BS5628 is wider in scope than CP111, containing sections on design to resist accidental damage and lateral loading.

During the later stages of drafting BS5628, the Code Committee was concerned that the changes being incorporated should not alter significantly the overall safety of masonry building. Therefore a programme of calibration calculations was commissioned by the Building Research Establishment to be carried out by Messrs Jenkins & Potter, Consulting Engineers, in collaboration with the Cement and Concrete Association and the Property Services Agency of the Department of the Environment. The calculations were made to compare designs to the draft BS5628 with those to CP111.

Whilst the new UK Code, BS5628, was in its final stages of preparation the CIB Commission W23A was preparing draft International Recommendations(3) for which a calibration exercise was also included in the commissioned work. This paper summarises the work done and gives the more important results.

CALCULATION MODELS: BS5628 COMPARED WITH CP111

Two major aspects of the codes needed investigation, viz:

(a) Compressive loading, both axial and eccentric,
(b) Lateral loading, arising from wind forces.

The major effort was expended on (a) since there was a previous Code, CP111 against which direct comparison could be made. No previous guidance had been given for lateral load design although CP111 contained two values for tensile strength. The work under (b) was, therefore, limited to comparison of BS5628 against the use of those two values and existing practice.

Compressive Loading

The programme was divided into several parts:

(a) a large number of calculations on individual walls and columns in brickwork (clay) and blockwork (concrete),
(b) a high rise loadbearing brickwork structure,
(c) a medium rise loadbearing cross wall structure, using both brickwork and blockwork.

BS5628 allows the partial safety factor for material to be varied according to the degree of manufacturing and site control. Four values are given: 3.5, 3.1, 2.8 and 2.1. For the calculations it was assumed that site control would be normal category, not special, but that bricks would qualify for the special category of manufacturing control, leading to $Y_m = 3.1$, whereas concrete blocks would be made to the normal category, giving $Y_m = 3.5$.

BS5628 contains different partial safety factors for dead load and imposed load, so the calculation needed to take different ratios of imposed and dead load into account; these were 0, 0.33, 1 and 3. At a ratio of 1 the overall partial safety factor for load Y_f is 1.5. The slenderness ratios used were 6, 12, 18, 24 and 27 and the ratios of eccentricity to overall thickness of wall were 0, 1/6, 1/4 and 1/3. Walls and columns were designed to the two Codes in several thicknesses of brickwork and blockwork, in different strengths of unit set in mortar appropriate to the strength of the brick or block (1:1/4:3, 1:1:6, 1:2:9).

A high rise loadbearing brick structure of 12 storeys to the plan shown in Fig 1 was designed to both Codes. The ground floor of a medium rise (9 storeys) structure was designed in brickwork and similar comparative calculations for the 5th floor were prepared in both brickwork and concrete blockwork.

Lateral Loading

The buildings described above required some lateral load (wind) calculations. In addition, BS5628 was used to calculate the limiting dimensions of a range of wall panels of varying shapes and forms of construction subjected to three wind loading conditions. The limits were compared subjectively with existing practice.

CALCULATION MODEL: BS5628 and CP111 COMPARED WITH THE CIB DRAFT MASONRY RECOMMENDATIONS

When submitting the 6th Draft of the CIB 'International Recommendations for Masonry Structures' to the members of the Commission W23A, the plan and specification of a 7-storey loadbearing structure was included, and national representatives were asked to do similar comparative calculations using the 6th Draft and their own national Code. There were difficulties with the 6th Draft and the 7th Draft has now been prepared and a request has been made for the calculations to be updated. A plan of the building is given in Fig 2.

In addition to asking Jenkins & Potter to carry out the trial calculations the Building Research Establishment also listed a number of walls to be designed, similar to the UK Code calibration calculations described previously. The CIB Draft gives little guidance on design to resist lateral loading, beyond a characteristic flexural strength comparable to the value in CP111. The calibration exercise therefore did not examine this aspect, apart from the overall stability of the trial building and its resistance to overturning.

RESULTS OF CALCULATIONS

Compressive Loading

The volume of the reports on the calculation exercises comparing designs to CP111 and the draft BS5628 would be close to equalling the proceedings of this Conference and so only sample results can be given. Table 1 is a typical sheet of results for compressive loading on a 102.5 mm thick brick wall of 20.5 N/mm² bricks in a 1:1:6 mortar. The ratios given are always load capacity using CP111 divided by that using BS5628: thus a ratio below unity means that designs to the new Code can carry more load. The ratios of all the calculations have been summarised in histogram form. Fig 3-A gives all the axial results and shows a well balanced grouping around unity, i.e., the two Codes give broadly similar results. Fig 3-B includes all eccentrically loaded walls and columns, and shows that there is almost always an increase in vertical load capacity when using the new Code, in some cases very considerable. The increases arise from the new treatment of the effects of eccentricity and slenderness in BS5628, although many of the extremely low ratios and those above unity occur at extreme slenderness ratios and extreme ratios of live to dead load.

After examination of the detailed and composite Fig 3-C results a number of alterations were made to the draft Code before the Code Committee agreed to publication on the basis that adequate margins of safety were being maintained by comparison with the more conservative aspects of CP111.

The calculations on the two multi-storey buildings used Y_m of 3.1 and 3.5 for both brickwork and blockwork. With special category manufacturing control the units required were on average one brick class lower or equivalent lower strength block than when using CP111. With Y_m of 3.5 corresponding to normal quality control the two Codes required broadly similar units for corresponding walls.

Lateral Loading

The lateral loading exercise was of considerable interest. For many years designers have used the two optional tension values from CP111 and they have tended to let one or other direction of span govern, thus not taking advantage of the two way action available in many panel walls. When panels were designed on this simple basis, BS5628 usually gave bigger panel sizes for a given wind load (or bigger wind load resistance for a given size). BS5628 now allows a bending moment approach to be used for panel walls in which a large range of ratios of flexural strength in the horizontal and vertical directions can be accommodated. When this approach was used with the two tension values in CP111, it was found that the panel sizes for a given load were much closer to those given by the new Code, and actually exceeded them for some low strength concrete blocks, for which the flexural strengths in BS5628 are lower than for other materials. The panel sizes derived from BS5628 generally compared well with existing practice, but there were some types of panel that have been built that cannot be justified when using the partial safety factors in BS5628.

The comparison of design to the UK Code and the CIB draft Recommendations has confirmed the considerable importance of calibration when International recommendations are being proposed in a form which may be a possible basis for a harmonized Eurocode or an international ISO code. The UK Code BS5628 requires brick strengths only about *one half* of those needed when the 7th Draft of the CIB recommendation is used. The major difference between the two documents lies in the reduction factors for slenderness and eccentricity effects, but it is essential to compare the complete package of compressive strength, safety factors, eccentricity and reduction factors, etc. and not to consider only individual aspects in isolation.

CONCLUSIONS

From comparison of the new UK Code BS5628, with the existing CP111, it has been concluded that:

(a) for axially loaded walls, the load capacity is similar when designs are made to each Code,
(b) for eccentrically loaded walls, the load capacity under BS5628 is enhanced, often considerably, while still retaining an acceptable level of safety,
(c) example buildings designed to the new Code in general show improved economy with adequate safety maintained,
(d) the lateral load resistance of walls designed to BS5628 compares well with most existing practice and with the more sophisticated use of the two optional tension values in CP111.

The CIB draft Recommendations are extremely conservative compared to BS5628 (or CP111). It is therefore essential that new Codes, national or international, are not

introduced without prior calibration against existing Codes and practice to ensure that there are no adverse economic or safety effects.

ACKNOWLEDGEMENTS

The work described has been carried out as part of the research programme of the Building Research Establishment of the Department of the Environment and this paper is published by permission of the Director.

The help given by the Cement and Concrete Association and the Directorate of Civil Engineering Services of the Property Services Agency is gratefully acknowledged, together with that of Messrs Alan Rawson and Geoffrey Burton of Jenkins & Potter.

REFERENCES

1. British Standards Institution. CP111:1970, Structural Recommendations for Loadbearing Walls. British Standards Institution, London, 1970.
2. British Standards Institution. BS5628: Part 1: 1978, Structural Use of Masonry:Part 1: Unreinforced Masonry. British Standards Institution, London, 1978.
3. CIB W23A. Draft International Recommendations for Masonry Structures: 7th Draft 1979.

TABLE 1—Load Capacity Ratios For 102.5 mm Solid Brick Wall, Unit Strength 20.5 N/mm², Mortar Designation (iii)

Slenderness Ratio	Load Ratio Live/dead	Capacity Ratio CP 111/BS 5628 Eccentricity 0	1/6	1/4	1/3
6	0	0.92	0.79	0.79	0.78
	0.33	0.96	0.82	0.82	0.81
	1	0.99	0.85	0.85	0.84
	3	1.02	0.88	0.87	0.86
12	0	0.85	0.62	0.59	0.58
	0.33	0.88	0.64	0.61	0.60
	1	0.91	0.66	0.63	0.62
	3	0.94	0.68	0.65	0.64
18	0	0.81	0.51	0.42	0.33
	0.33	0.84	0.53	0.43	0.34
	1	0.87	0.55	0.45	0.35
	3	0.90	0.56	0.46	0.36
24	0	0.86	0.50	0.37	—
	0.33	0.89	0.52	0.38	—
	1	0.92	0.54	0.40	—
	3	0.95	0.56	0.41	—
27	0	0.95	0.53	—	—
	0.33	0.98	0.55	—	—
	1	1.01	0.57	—	—
	3	1.05	0.58	—	—

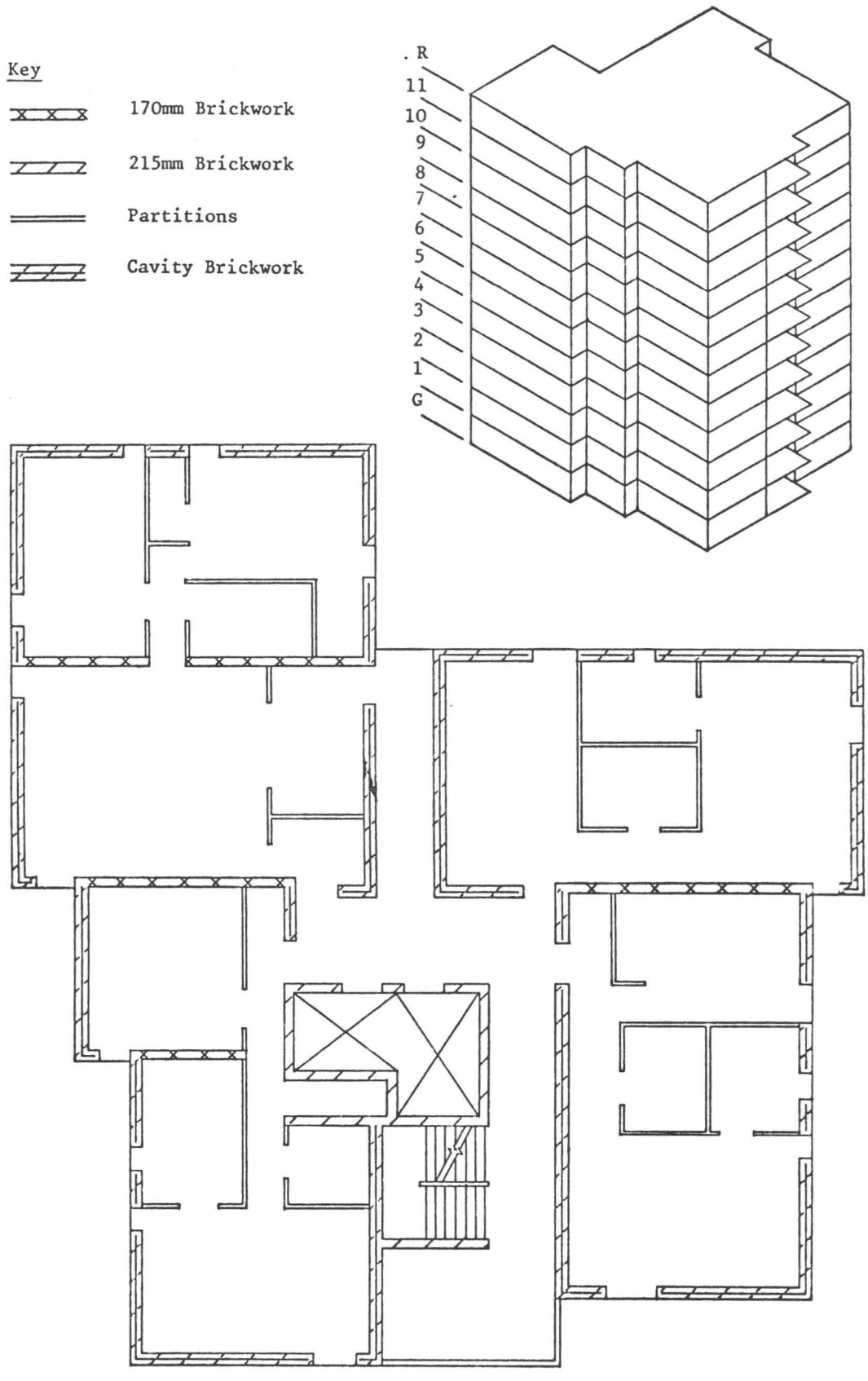

Figure 1. Plan and Isometric of High Rise Building.

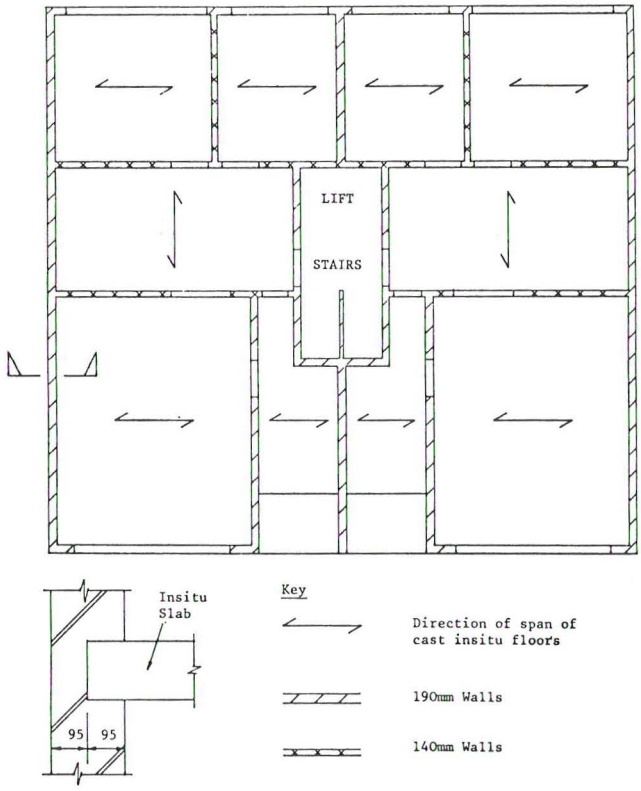

Figure 2. Plan of 7 Storey CIB Building.

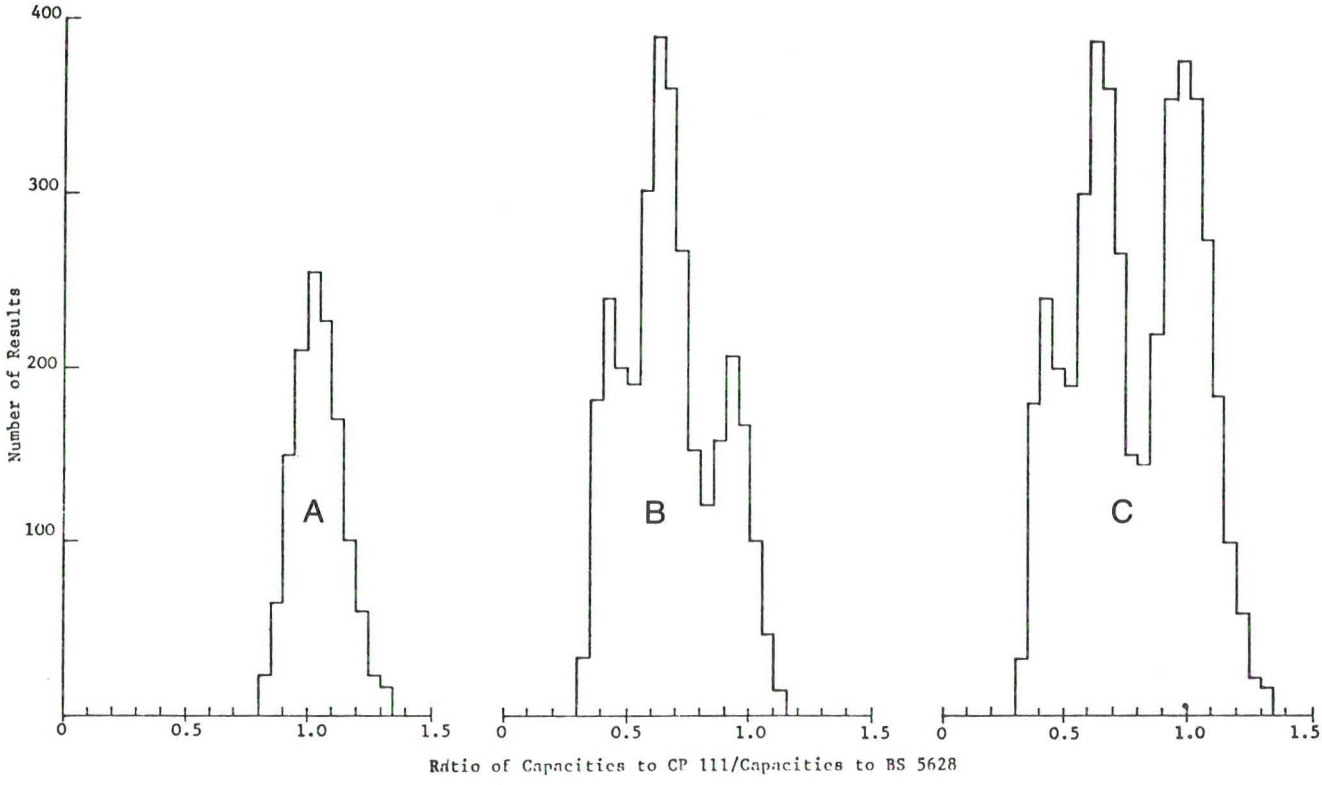

Figure 3. A) All Axial Loads, B) all eccentricities C) all calculations