Possible Causes of Cracks at Klang Mosque

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURAZZURA BINTI MOHD. FUZI

ABSTRACT

This research project is focused on the evaluation and assessment of cracks appeared in the structural members of Klang Mosque. There are many different kinds of cracks that sometimes are not serious and are probably due to shrinkage of concrete. Thus, in order to find out whether the cracks are because of serious causes such as settlement or design fault, the crack has to be identified and the causes must be studied in order to prevent building failure from likely to happen.

In order to determine the possible causes of cracks this study is based in three levels. In the first level, site inspection was made and cracks were physically inspected and were mapped out on sketches, the information included the orientation location and size of cracks. In the second level of assessment structural analysis and design of cracked elements is made and it is compare with the actual design in order to determine whether the design short falls caused any cracks. In the third level some NDT (non-destructive test) is to be performed in order to assess the quality of work and properties of in-situ materials such as concrete.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1. BACKGROUND OF STUDY

The study concerns a double storey mosque which is still under construction of its ground floor. The mosque is located in Klang town next to Pasar Jawa. The building is constructed beside the Klang River and the soil on which the building is constructed is of soft marine clay. The mosque is subjected to flooding at times. The mosque is designed to have 3 floors with a 60m tall minaret. At the time when crack was noticed, only the ground floor is being constructed which indicates that loading had not been applied fully yet. Severe cracks are found at the slabs at the centre of the building while construction is still taking place. By observation, the crack hair line is small and it is less than 0.3mm. The crack appeared at the slabs from Grid E-Y/14-18. It is long and continuous. The reinforcement diameter used is 10mm and the concrete strength is 30 N/mm^2. The construction has been abandoned for quite some time because of this cracking. Because of this, the study is needed to find the possible causes of cracks that took place at the building.

2. PROBLEM STATEMENT

There are a lot of causes that can lead to cracking in concrete. It ranges from non-severe and can be easily remediate to severe cases such as differential settlement which can be very harmful to the integrity of a building. The problem is at first suspected because of the weak marine clay soil which can cause differential settlement but précised surveying done did not show any changes in settlement. Thus, a case study as this will help to identify the cause of these cracks and provide suggestion for its remedial and future prevention so that this building is safe for use.

3. OBJECTIVE AND SCOPE OF STUDY

The main objective of this study is:

- To investigate the type of cracks that occurred at the Klang Mosque site by observing the crack mapping done.
- To identify whether it is the design fault or poor construction practice that causes the crack.
- To provide suggestion for remediation of the concrete cracks.

In order to achieve those two objectives, the scope of work of this study will be carried out in the following stages:

- Studying the location of cracks at the building whether it is located at structure parts (such as beams or columns) or non-structure parts (such as walls or floors). The crack mapping will be done to identify the type of cracks at the building.
- Review the settlement members, soil bore log and piling record of the construction to identify the causes of cracks.
- Do analysis of the affected slabs using EsteemPlus 6.2.5.8 software and check its calculation manually and then compare it with the original design.
- Do calculations to check shrinkage cracking and flexural cracking of the concrete slabs.
- Carry out non-destructive testing to check the strength of the concrete used.
- Suggest remediation for the problem found.

CHAPTER 2

LITERATURE REVIEW

1. CONCRETE CRACKING AND REPAIRS

Though concrete is a relatively durable building material, it may suffer *damage* or *distress* during its life period due to a number of reasons. Because of the varying conditions under which it is produced at various locations, the quality of concrete suffers occasionally either during production or during service conditions resulting in distress. The structural causes of distress of concrete may include externally applied and environmental loads exceeding the design stipulations, accidents and subsidence. Sometimes distress in a structure is brought about by *poor construction practices, error in design and detailing*, and *construction overloads*. The other causes may be *drying shrinkage, thermal stress, weathering, chemical reactions* and *corrosion of reinforcement*. In addition to the distress in hardened concrete the plastic concrete may also suffer damage due to *plastic shrinkage* and *settlement cracking*. Sometimes on stripping off the forms a number of surface defects such as bulges, ridges, *honeycombing, bolt holes*, etc. are noticed on the fresh concrete members. Such defects can be avoided to a large extent by providing a watertight and rigid formwork in such a way that stripping can be done without the use of crowbars or other tools. In addition to these defects, *blow-holes* develop during concreting operations due to improper design of *formwork*. These can be reduces if the form face is slightly absorbent and adequate compaction is provided. In case the blow-holes are exceptionally large, or if a smooth surface is required, they must be filed with 1:1 or 1:2 cement-sand mortars. The sand should be sieved through a 300μm or 600μm sieve, depending upon the smoothness of the finish required. Crushed limestone dust is preferable. The mortar should be rubbed over the affected area with a rubber-faced float, and finally rubbed down with a smooth stone or mortar block for a smooth finish.

The *honeycombing* consisting of groups of interconnected deep voids normally indicate inadequate compaction or loss of grout through joints in formwork or between formwork and previously cast-concrete. The affected area is delineated with a saw cut to a depth of 5mm. The unsound material is chipped out to the solid concrete. After the surface has been prepared a bonding coat should be applied to all exposed surfaces, and new concrete should be placed against the prepared surface. The bonding coat may consist of a slurry of cement and water, but it is desirable to incorporate a polymer admixture.

The repair of bulges and projections can be carried out by chipping off the concrete from the surface and then rubbing the surface with a grinding stone. Scouring of a vertical surface of hardened concrete making it resemble a map of delta of a river is caused by water moving upward against the face of formwork. This is a sign of excessive wet or harsh concrete. It is a superficial defect so, unless it is unusually deep and the cover to reinforcement is unusually small, the remedial measures consist of early facing up in the same way suggested for filling *blow-holes*.

This type of repair (more appropriately called *finishing*) should be done as soon as possible after the forms are stripped and before the concrete becomes too hard. The repair should be preferably be completed within 24 hours of the removal of the forms. This is done to develop a good bond and make the repaired portion as durable and permanent as the original work.

If the repairs are not properly done, the newly placed concrete becomes *loose* and *drummy* with the passage of time and finally gets detached from the main concrete. The darker colour of the repaired patches can be corrected by adding 10 to 20 percent white Portland cement to the patching mortar to obtain uniform surface colour. The various defects occurring during construction are outlined in Appendix I.

2. SYMPTOMS AND DIAGNOSIS OF DISTRESS

In addition to minor structural defects outlined above, the other distresses can be observed in the form of cracks, spalling and scaling of concrete. Cracking is the most common indication of the distress in a concrete structure. It may affect appearance only, or indicate significant structural distress of lack of durability. Cracks may represent the total extent of the damage, or they may point to the problems of greater magnitude. These, in turn, may cause corrosion of reinforcement due to the entry of moisture and oxygen.

All the concrete structures crack in some form or the other. Most buildings develop cracks in their fabric which are superficial and occur soon after the construction. Cracks, even if harmless, may have and adverse psychological effect. However, cracking in concrete structures is not necessarily a cause for accusing the designer, builder or supplier. What really matters is the type of structure and the nature of *cracking*. Cracks that are acceptable for building structures may not be acceptable for water-retaining structures.

Cracking of concrete structures can never be totally eliminated, but the practitioner should be aware of the causes, evaluation techniques, and the methods of repair. The approach to diagnosis of the problem of cracking should be identical to that of a doctor to the patient. An engineer should have a sound knowledge of all the facets of concrete technology, i.e. of the behaviour of construction materials, construction techniques, types of cracks likely to occur, their causes and respective remedial measures. In short, treatment of cracks involves detection, diagnosis and remedy. Before remedies are sought, correct diagnosis will decide whether satisfactory repair is possible. The development of cracks and their repair is a *perpetual* problem involving considerable cost and inconvenience to the occupants. The problem should be tackled on two fonts, i.e. by adopting preventive measures and repairing them. However, prevention is better than repair. The designer and builders should attempt to reduce the formation of cracks by using appropriate construction materials, and by adopting appropriate design and construction techniques.

The cracks in a structure are broadly classified in two categories: *superficial cracks* and *structural cracks*. The structural cracks may be *active* and *dormant*. A crack where a movement is observed to continue is termed active, whereas the crack where no movement occurs is termed dormant or static. The following information may help in diagnosing the cracks:

(i) whether the crack is new or old

(ii) type of crack, i.e. whether it is active or dormant

(iii) whether it appears on the opposite of the face of the member also

(iv) pattern of the cracks

(v) soil condition, type of foundation used, sign of movement of ground, if any

(vi) observations on the similar structures in the same locality

(vii) study of specifications, method of construction used and the test results at the site, if any

(viii) views of the designer, builder, occupants of the building, if any

(ix) weather during which the structure has been constructed

From the above discussion it is evident that the cracking is a complex phenomenon. The various aspects of the problem are discussed as follows.

The latent defects in a concrete structure may be caused by inadequacy of design, materials or construction practices which may not become evident until sometime after its completion. The immediate cause of deterioration may be a chemical action or corrosion of reinforcement, but in majority of the cases the basic cause may be traced back to something such as unrealistic detailing or poor workmanship.

The incompatible dimensional changes caused by drying shrinkage and thermal movements during and after the hardening period may also cause cracks in concrete members. Before any repair work is taken in hand, the cause of damage must be clearly identified, for which careful investigation is required.

3. CRACKING OF HARDENED CONCRETE

The moisture-induced volume changes are characteristic of concrete. A loss of moisture from cement paste results in a volume shrinkage by as much as 1 percent, whereas the internal restraint provided by the aggregate reduces the magnitude of this volume change to about 0.05 percent. On the other hand, an increase in moisture in the concrete tends to increase its volume. If these volume changes are restrained (usually by another part of structure or by the subgrade), the tensile stresses develop.

When the tensile strength of concrete is exceeded, it will crack. The cracks may propagate at much lower stresses than are required to cause *crack initiation*. In massive concrete elements, tensile stresses are caused by differential shrinkage between the surface and the interior concrete. The larger shrinkage at the surface causes the cracks to develop that may with time penetrate deeper into the concrete. *Surface cracking* on walls and slabs usually occurs due to drying shrinkage when the surface layer of concrete has higher water content than the interior concrete. The *surface crazing* appears in the form of a series of shallow, closely spaced fine cracks.

The extent of shrinkage cracking depends upon the amount of shrinkage, degree of restraint, modulus of elasticity and amount of creep. The amount of drying shrinkage is influenced mainly by the amount and type of aggregate and the water content of the mix. The shrinkage decreases with the increase in the amount of aggregate and the reduction in *water content*. The higher the stiffness of the aggregate, the more of effective it is in reducing the shrinkage of concrete, e.g. the shrinkage of concrete containing sandstone aggregate may be more than twice that of concrete with basalt or granite. Therefore, the drying of shrinkage can be reduced by using the maximum practical amount of aggregate and lowest usable water content in mix. Shrinkage cracking can be controlled by using properly spaced *contraction joints* and proper *steel detailing*. The shrinkage cracking can also be controlled by using *shrinkage compensating cement*.

3.1 Cracking Due to Poor Construction Practices

Poor construction practices, such as adding water to concrete to improve workability, lack of curing, inadequate form support, inadequate compaction and arbitrary placement of construction joints, can result in cracking in concrete structures. Adding water to improve workability has the effect of reducing strength, increasing settlement and ultimate drying shrinkage. The early termination of curing will allow for increased shrinkage at the time when the concrete has low strength. Incomplete hydration due to drying will reduce not only the long term strength but also the *durability* of the structure. Lack of support for forms or inadequate compaction can result in the *settlement cracking* of concrete before it has developed sufficient strength to support its own weight, while improper location of construction joints can result in cracking at the planes of weakness. Some of the defects occurring during construction are summarized in Appendix I.

3.2 Cracking Due to Construction Overloads

The loads induced during construction can be far more severe than those experienced in service. Unfortunately, these conditions may occur at the early ages when the concrete is most susceptible to damage and often result in permanent cracks.

A common error occurs when the precast members are not properly supported during transportation and erection. The use of arbitrary or convenient lofting points may cause severe damage. A big element lowered too fast, and stopped suddenly carries significant momentum which is translated into an impact load that may be several times the dead weight of the element.

Storage of materials and equipment can easily result in loading conditions during construction far more severe than any load for which the structure is designed. Damage from unintentional construction overloads can be prevented only if the designers provide information on load limitations for the structure and if the construction personnel heed to these limitations.

3.3 Cracking Due to Errors in Design and Detailing

The design and detailing errors that may result in unacceptable cracking include use of poorly detailed re-entrant corners in walls, precast members and slabs; improper selection and/or detailing of reinforcement; restraint of members subjected to volume changes caused by variations in temperature of moisture; lack of adequate contraction joints, and improper design of foundations resulting in differential settlement within the structure. Reentrant corners provide a location for stress concentration and therefore, are prime locations for cracks, as in the case of window and door openings in concrete walls and dapped beams. Additional properly anchored diagonal reinforcement is required to keep inevitable cracks narrow and prevent them from propagating further.

An inadequate amount of reinforcement may result in excessive cracking. A common mistake is to lightly reinforce an element because it is a non-structural element and tying it to the rest of the structure in such a manner that it is required to carry a major portion of the load once the structure begins to deform. The non-structural element will carry a load in proportion to its stiffness. Since this element is not detailed to act structurally, unsightly cracking may result even though the safety of the structure is not threatened. The restrained members subjected to volume changes frequently develop cracks. A slab, wall or a beam restrained against shortening, even if prestressed, can easily develop tensile stress sufficient to cause cracking. Beams should be allowed to move.

Improper foundation design may result in excessive differential movement within a structure. If the differential movement is relatively small, the cracking problem may be only visual in nature. However if there is a major differential settlement, the structure may not be able to redistribute the loads rapidly enough, and a failure may occur. One of the advantages of the reinforced concrete is that, if the movement takes place over a sufficiently long period of time, creep will allow some redistribution of load.

Special care needs to be taken in the design and detailing of structures in which cracking may cause a major serviceability problem. These structures also require continuous inspection during all phases of construction to supplement the careful design and detailing.

3.4 Cracks Due to Externally Applied Loads

Load-induced tensile stresses may result in cracks in concrete elements. A design procedure specifying the use of reinforcing steel, not only to carry tensile forces, but also to obtain both an adequate crack distribution and a reasonable limit on crack width is recommended. Flexural and tensile crack widths can be expected to increase with time for members subjected to either sustained or repetitive loading. A well-distributed reinforcing arrangement offers the best protection against undesirable cracking.

4. EVALUATION OF CRACKS

As in the case of a medial practitioner prescribing medicine without thoroughly examining the patient, it is difficult for a repair engineer to advocate any repair technology without making a thorough investigation. Before proceeding with repair, the investigations should be made to determine the location and extent of cracking, the causes of damage and the objectives of repair. Calculation can be made to determine stresses due to applied loads. For detailed information, the history of the structure, structural drawings and specifications, and construction and maintenance records should be reviewed.

The objectives of repair include restoration and enhancement of durability, structural strength, functional requirements and aesthetics. The evaluation of cracks is necessary for the following purposes:

- (i) To identify the cause of cracking
- (ii) To assess the structure for its safety and serviceability
- (iii) To establish the extent of the cracking
- (iv) To establish the likely extent of further deterioration
- (v) To study the suitability of various remedial measures
- (vi) To make a final assessment for serviceability after repairs

Apart from visual inspection, tapping the surface and listening to the sound for hollow areas may be one of the simplest methods of identifying the weak spots. The suspected areas are then opened up by chipping the weak concrete for further assessment.

The comparative strength of concrete in the structure may be assesses to a reasonable accuracy by non-destructive testing and by the tests on the cores extracted from the concrete. The commonly used non-destructive tests are the rebound-hammer test and ultrasonic-pulse-velocity test.

5. FLEXURAL CRACKING

Members subjected to bending generally exhibit a series of distributed flexural cracks, even at working load. These cracks are unobtrusive and harmless unless the widths become excessive, in which case appearance and durability suffer as the reinforcement is exposed to corrosion.

The actual width of cracks in a reinforced concrete structure will vary between wide limits and cannot be precisely estimated thus the limiting requirement to be satisfied is that the probability of the maximum width exceeding a satisfactory value is small. The maximum acceptable value suggested by BS8110 is 0.3mm at any position on the surface of the concrete in normal environments although some other codes of practice recommend lower values for important members. Requirements for specialised cases such as water-retaining structures may be more stringent.

If calculations to estimate maximum crack widths are performed, they are based on 'working' loads with $\gamma_f = 1.0$ and material partial factors of safety of $\gamma_m = 1.0$ for steel and concrete. BS 8110 recommends that the effective modulus of elasticity of the concrete should be taken as half the instantaneous value as given in Table 1, to allow for creep effects.

28-day characteristic cube strength $f_{cu,28}$ (N/mm^2)	Static modulus $E_{c,28}$ (kN/mm^2)	
	Typical range	Mean
25	19-31	25
30	20-32	26
40	22-34	28
50	24-36	30
60	26-38	32

Table 1: Short-term modulus of elasticity of concrete

5.1 Mechanism of Flexural Cracking

This can be illustrated by considering the behaviour of a member subjected to a uniform moment.

A length of beam as shown in Figure 1 will initially behave elastically throughout as the applied uniform moment M is increased. When the limiting tensile strain for the concrete is reached a crack will form and the adjacent tensile zone will no longer be acted upon by direct tension forces. The curvature of the beam, however, causes further direct tension stresses to develop at some distance from the original crack to maintain internal equilibrium. This in turn causes further cracks to form and the process continues until the distance between cracks does not permit sufficient tensile stresses to develop to cause further cracking. These initial cracks are called 'primary cracks', and the average spacing in a region of constant moment has been shown experimentally to be approximately 1.67 $(h\text{-}x)$ and will be largely independent of reinforcement detailing.

As the applied moment is increased beyond this point, the development of cracks is governed to a large extent by the reinforcement. Tensile stresses in the concrete surrounding reinforcing bars are caused by bond as the strain in the reinforcement increases. These stresses increase with distance from the primary cracks and may eventually cause further cracks to form approximately midway between the primary cracks. This action may continue with increasing moment until the bond between concrete and steel is incapable of developing sufficient tension in the concrete to cause further cracking in the length between existing cracks. Since the development of the tensile stresses is caused directly by the presence of the reinforcing bars, the spacing of the cracks will be influenced by the spacing of the reinforcement. If bars are sufficiently close for their 'zone of influence' to overlap then secondary cracks will join up across the member while otherwise they will form only adjacent to the individual bars. It has been confirmed experimentally that the average spacing of cracks along a line parallel to, and at a distance a_{cr} from, a main reinforcing bar depends on the efficiency of bond and may be taken as 1.67 a_{cr} for deformed bars, or $2.0a_{cr}$ for plain round bars.

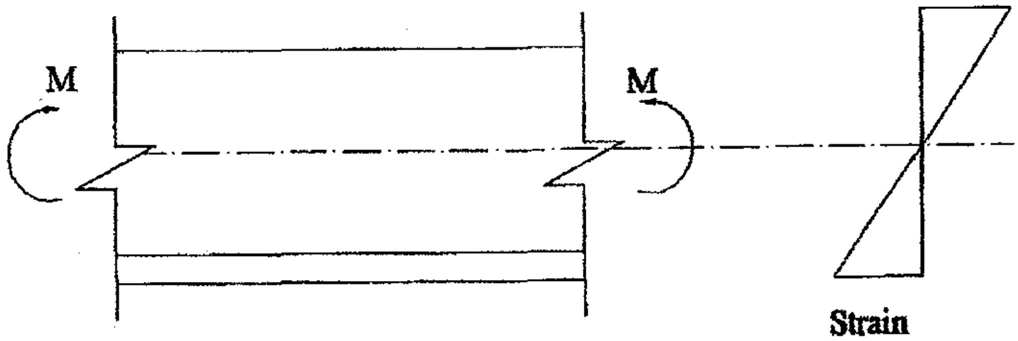

Figure 1: Bending of a length of a beam

6. ULTRA PULSE VELOCITY TEST

At present the ultrasonic pulse velocity method is the only one of this type that shows potential for testing concrete strength in situ. It measures the time of travel of an ultrasonic pulse passing through the concrete. The fundamental design features of all commercially available units are very similar, consisting of a pulse generator and a pulse receiver. Pulses are generated by shock-exciting piezo-electric crystals, with similar crystals used in the receiver3. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits.

Pulse velocity tests can be carried out on both laboratory-sized specimens and completed concrete structures, but some factors affect measurement:

1. There must be smooth contact with the surface under test; a coupling medium such as a thin film of oil is mandatory.
2. It is desirable for path-lengths to be at least 12 in. (30 cm) in order to avoid any errors introduced by heterogeneity.
3. It must be recognized that there is an increase in pulse velocity at below-freezing temperature owing to freezing of water; from 5 to 30°C (41 - 86°F) pulse velocities are not temperature dependent.
4. The presence of reinforcing steel in concrete has an appreciable effect on pulse velocity. It is therefore desirable and often mandatory to choose pulse paths that avoid the influence of reinforcing steel or to make corrections if steel is in the pulse path.

6.1 Applications and Limitations

The pulse velocity method is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction. Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present.

High pulse velocity readings are generally indicative of good quality concrete. A general relation between concrete quality and pulse velocity is given in Table 2.

General Conditions	Pulse Velocity, ft/sec
Excellent	Above 15,000
Good	12,000-15,000
Questionable	10,000-12,000
Poor	7,000-10,000
Very Poor	below 7,000

Table 2: Quality of Concrete and Pulse Velocity

Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ±20 per cent, provided the types of aggregate and mix proportions are constant.

The pulse velocity method has been used to study the effects on concrete of freeze-thaw action, sulphate attack, and acidic waters. Generally, the degree of damage is related to a reduction in pulse velocity. Cracks can also be detected. Great care should be exercised, however, in using pulse velocity measurements for these purposes since it is often difficult to interpret results. Sometimes the pulse does not travel through the damaged portion of the concrete.

The pulse velocity method can also be used to estimate the rate of hardening and strength development of concrete in the early stages to determine when to remove formwork. Holes have to be cut in the formwork so that transducers can be in direct contact with the concrete surface. As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength, so that beyond a strength of 2,000 to 3,000 psi (13.6 to 20.4 MPa) accuracy in determining strength is less than ±20%. Accuracy depends on careful calibration and use of the same concrete mix proportions and aggregate in the test samples used for calibration as in the structure.

In order to determine the strength of concrete, the results from UPV test can be plotted in a chart developed by P. Turgut as shown in the figure below.

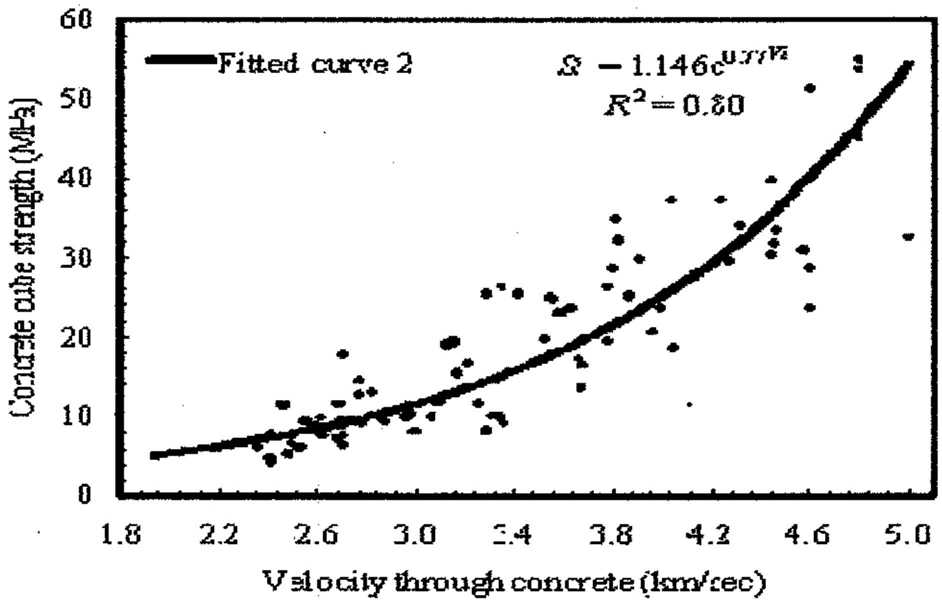

Figure 2: Relationship between concrete strength and UPV in existing reinforced concrete structures

In summary, ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity.

CHAPTER 3

METHODOLOGY AND PROJECT WORK

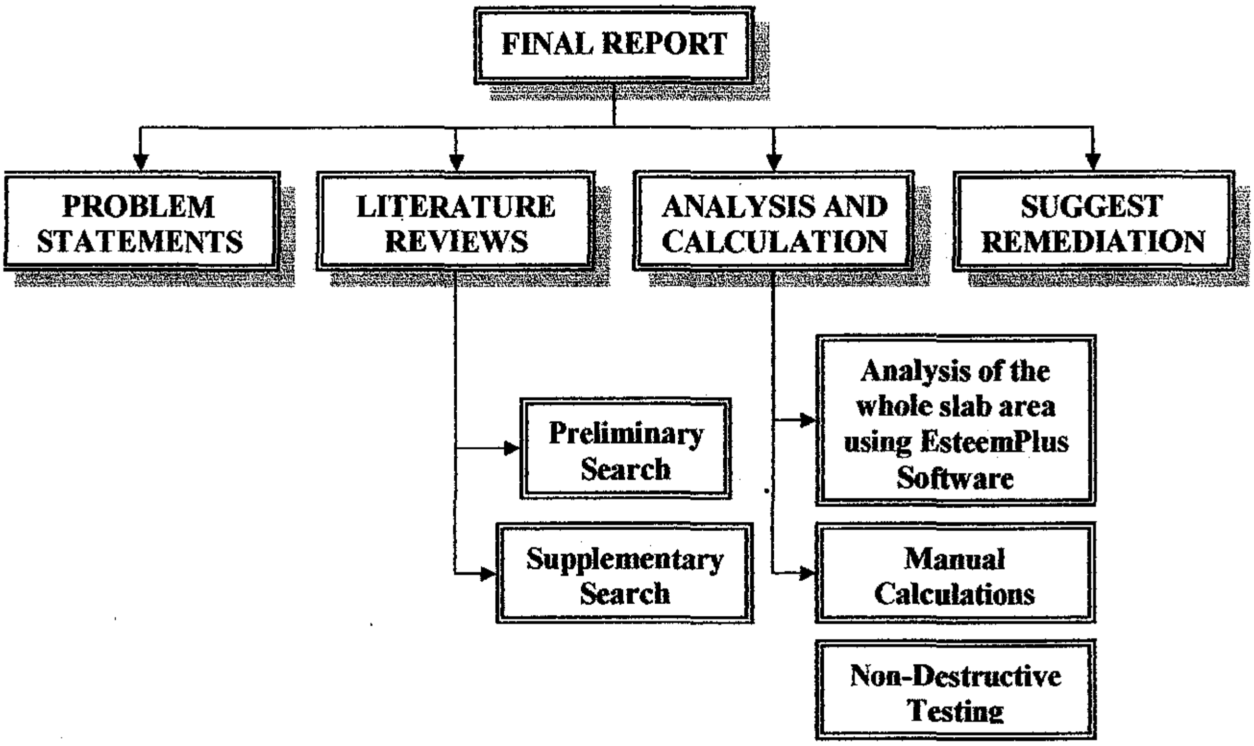

Figure 3: Work Breakdown Structure

1. VISUAL EXAMINATION

The appearance of concrete surface may suggest the possibility of chemical attack by general softening and leaching matrix, or in case of sulphate attack by whitening of concrete. Rust stains often indicate corrosion of reinforcement but they may also be caused due to the contamination of aggregate with iron pyrites. If the cracked concrete is broken out, the appearance of the crack surface gives useful information; dirt or discolouration show that the crack has been there for some time. General flaking of an exposed concrete surface suggests frost damage. In fire damaged structure, the colour of concrete gives an indication of the maximum temperature reached.

The crack pattern may be informative, a mesh pattern suggests drying shrinkage, and surface crazing may indicate frost attack or in rare cases alkali-aggregate reaction. The cracks caused by unidirectional bending will be the widest in the zone of maximum tensile stress and will taper along their length, while cracks caused by direct tension will be of roughly uniform width. Pop-outs in concrete are usually associated with particles of coarse aggregate just below the surface.

The location and width of cracks should be noted on a sketch of the structure. A grid marked on the surface of the structure can be used to accurately locate cracks on the sketch. Crack widths can be measure to accuracy of about 0.025 mm using a crack comparator, which is a small hand-held microscope with a scale on the lens closest to the surface being viewed. Location of observed spalling, exposed environment, surface deterioration and rust staining should be noted on the sketch.

The use of brittle liquid coatings on the suspected structure can also help detect the crack or growth of cracks over a period of time. The movement of the crack can be monitored with the help of mechanical movement indicators or crack monitors using electrical resistance thin filaments which amplify crack movement and indicate the maximum range of movement occurring during the measurement period, i.e. the extent of progressive growth of crack. Linear variable differential transformers (LVDTs) and data acquisition systems (ranging from strip chart recorder to a computer based system) are available. The cracks in concrete may be evaluated at macro, micro, submicro and atomic levels (Angstroms Å). In the present discussion the macrostructure cracks having a size (i.e. width/depth) in the range of 0.1 to 0.3mm are of interest.

2. ESTEEMPLUS 6.2.5.8

The EsteemPlus 6.2.5.8 is a software used to do design analysis of affected slabs. This software is a local software by Esteem Innovation Sdn. Bhd.. It is useful enough to do simple analysis and calculations for this case study.

2.1 Key Features of EsteemPlus 6.2.5.8

It has user friendly interface which capitalises on the Windows environment and it eliminates the chore of remembering key commands for input. It provides efficiency as well as user functionality. It has feature of 3D Environment which able the display of the structure in 3D view for better visualization and presentation. It also includes 3D analysis. In this version, it has added more functions on slab in which a user can put loadings on slab such as line and point load, cantilever load and even customize an irregular slab. It also allows batch run of analysis of all floors simultaneously.

There are a series of e-tutorial designed to the user to learn and quickly familiarize with the functions of EsteemPlus. Among the tutorials are creating project and input grid, input liftcore and RC wall, input beam, input column and lateral load, input slab, analyze and design slabs, analyze beam, duplicate floor, generate and analyze 3D frame, design beam, design column, wall, pad and pile footing. A user can set the parameters for the design; detailing and project parameters such as the code of practice, load factor, characteristic strength and design parameters for each part of structure (slabs, beams, columns, etc.). There are 5 modules of input in the key plan input mode and these are detailed as follows:

- Input grid – To access the grid input for both *x* and *y* direction grid.
- Input beams – To access beam input for both *x* and *y* direction beams.
- Input slabs – To access the input for slabs.
- Input columns – To access the input for columns.
- Input RC Wall – To access wall/liftcore input.

The analysis modules consist of the following:

- Generate Slab Mesh – Generates mesh for the slab.
- Analyse FEM Slab – Analyses the slab using Finite Elements Method.
- Design Slab – To run the analysis for slabs either using FEM or conventional analysis method.

- Analyse Beam – To run the analysis for floor beams and collate the reactions. Checks if the beam passes the deflection check for that floor only.
- 3D Frame Element – Analyses the whole structure as a frame.
- Design Beam – Run the analysis and designs the beam for the floor.

2.2 Process of Analyzing

1. Input the grids according to the original layout plan of Klang Mosque.

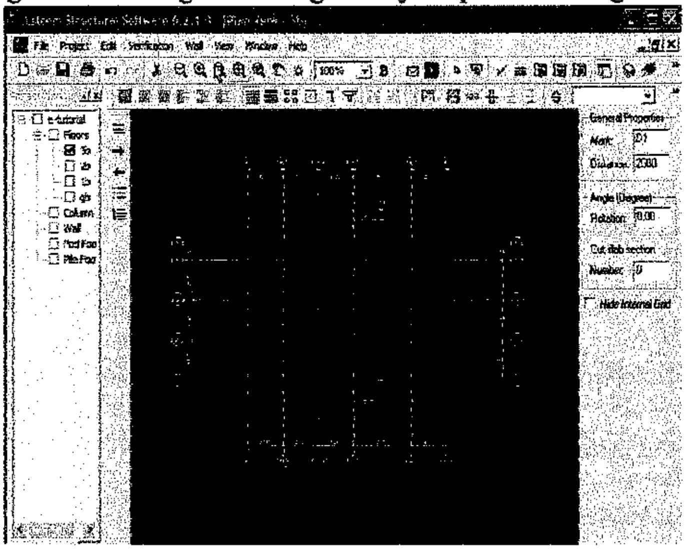

Figure 4: Grids input

2. Next, the beam is put in place according to the original layout plan with the same sizes.

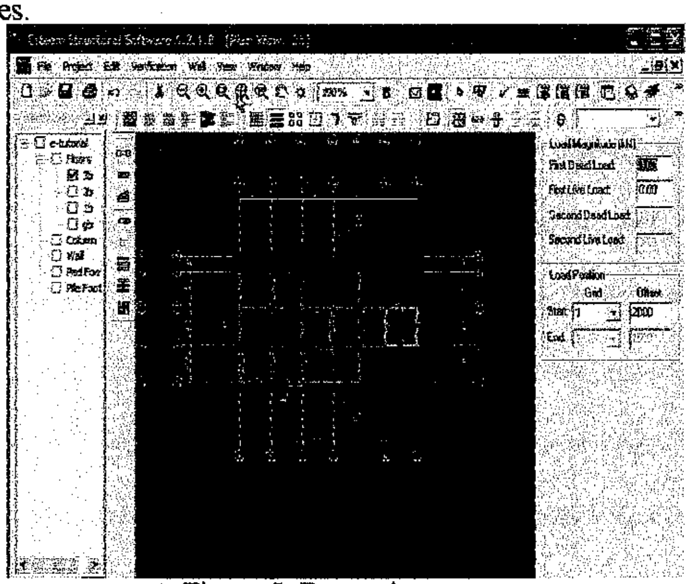

Figure 5: Beams input

3. Then, the column can be put in place according to the exact same location and sizes as the original layout.

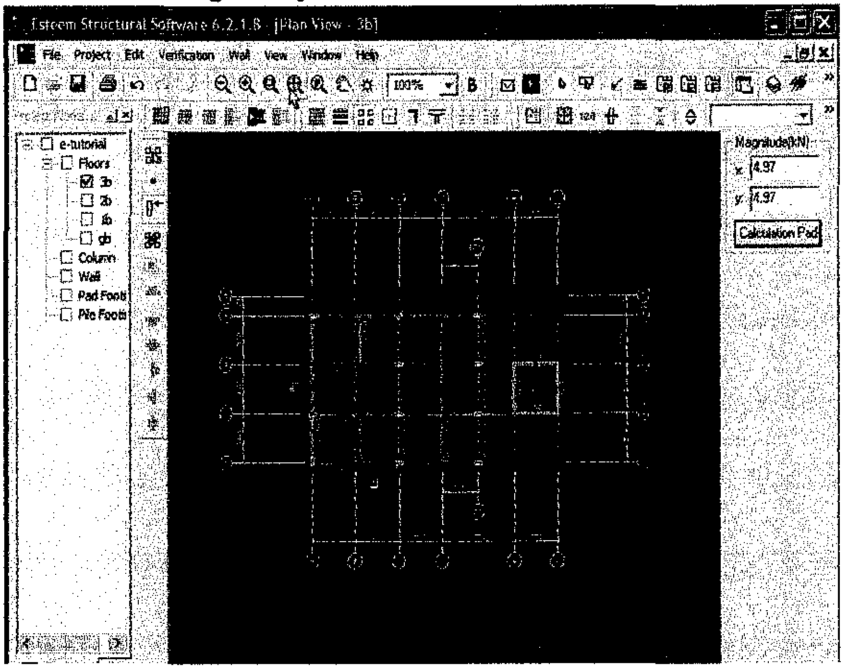

Figure 6: Columns input

4. Input of slabs is according to the same thickness, drops and with the finishes load is taken as $1.7kN/m^2$ and live load is taken as $5kN/m^2$. This is taken from BS6399: Part 1: 1984 Table 7 – Assembly areas without fixed seating (can be referred also in Appendix 7).

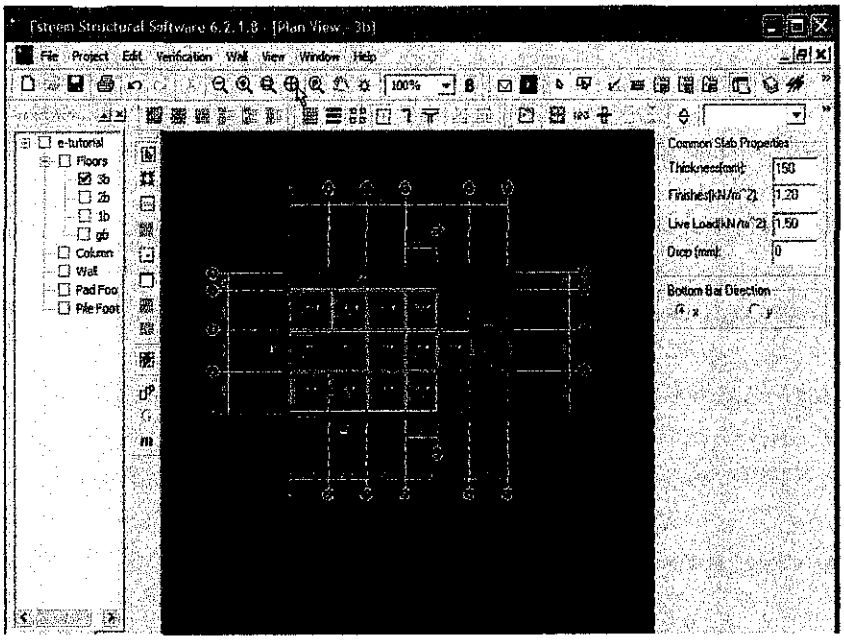

Figure 7: Slabs input

3. THERMAL AND SHRINKAGE CRACING

After cracking, the equilibrium of concrete adjacent to a crack is as illustrated in Figure 8.

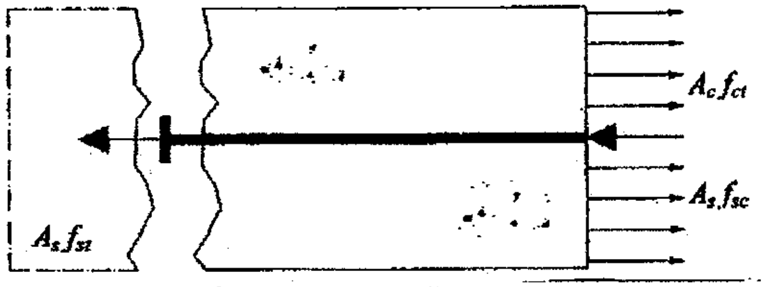

Figure 8: Forces adjacent to a crack

Equating tension and compression forces

$$A_s f_{st} = A_c f_{ct} - A_s f_{sc}$$

or

$$f_{ct} = \frac{A_s}{A_c}(f_{st} + f_{sc})$$

If the condition is considered when steel and concrete simultaneously reach their limiting values in tension, that is, $f_{st} = f_y$ and $f_{ct} = f_t$ = tensile strength of concrete at appropriate age – usually taken as three days, then

$$r = \frac{A_s}{A_c} = \frac{f_t}{f_y + f_{sc}}$$

where r is the steel ratio.

The value of f_{sc} can be calculated but is generally very small and may be taken as zero without introducing undue inaccuracy; hence the critical value of steel ratio

$$r_{crit} = \frac{A_s}{A_c} = \frac{f_t}{f_y + f_{sc}} \text{ approximately}$$

If the steel ratio is less than this value, the steel will yield in tension resulting in a few wide cracks; however if it is greater then more cracks will be formed when the tensile stress caused by bond between the steel and concrete exceeds the concrete tensile strength, that is

$$F_b s \sum u_s \geq f_t A_c$$

Where f_b = average bond stress

s = development length along a bar

Σu_s = sum of perimeters of reinforcement

For a round bar

$$\frac{u_s}{A} = \frac{4\pi\Phi}{\pi\Phi^2} = \frac{4}{\Phi}$$

Hence since

$$\sum u_s = \frac{A_s}{A} u_s \text{ for similar bars}$$

Then

$$\sum u_s = \frac{4rA_c}{\Phi}$$

and thus

$$s \geq \frac{f_t \Phi}{4rf_b}$$

The maximum crack spacing is twice this value immediately prior to the formation of a new crack, when the development length on both sides is s_{min}, that is

$$s_{max} = \frac{f_t \Phi}{2rf_b}$$

Crack spacing and hence width therefore is governed both by the reinforcement size and quantity for ratios above the critical value, which should be taken as a minimum requirement for controlled cracking.

3.1 Crack width Calculation for Thermal and Shrinkage Cracking

The expressions for crack spacing assume that the total thermal and shrinkage strains are sufficient to cause cracking, although in practice it is found that predicted cracks may not always occur. It is possible to estimate however the maximum crack width likely to occur by considering total concrete contraction in conjunction with the maximum likely crack spacing. For steel ratios greater than the critical value, and when the total contraction exceeds the ultimate tensile strain for the concrete (ε_{ult}), the tensile stress in the concrete increases from zero at a crack to a maximum value at mid-distance between cracks. Hence the mean tensile strain in the uncracked length is $\varepsilon_{ult}/2$ when a new crack is just about to form. The crack width is thus given by crack width = (total unit movement – concrete strain) x crack spacing with the maximum width corresponding to the maximum spacing of s_{max}

$$\omega_{max} = (\varepsilon_{sh} + T\alpha_c - \tfrac{1}{2}\varepsilon_{ult})\, s_{max}$$

where ε_{sh} = shrinkage strain

T = fall in temperature from hydration peak

α_c = coefficient of thermal expansion of concrete

In practice, variations in restraints cause large variations within members and between otherwise similar members, with 'full' restraint seldom occurring. The behaviour depends considerably on this and temperatures at the time of casting. Allowance for these influences, and creep, can be made by the use of 'restraint factors' so that the equation for maximum crack width becomes

$$\omega_{max} = [R\,(\varepsilon_{sh} + T\alpha_c) - \tfrac{1}{2}\varepsilon_{ult}]\, s_{max}$$

where R = restraint factor (maximum value 0.5 for 'full' restraint). Further guidance concerning possible 'restraint factors' is given in Part 2 of BS 8110.

4. ESTIMATION OF CRACK WIDTHS FOR FLEXURAL CRACKING

If the behaviour of the member in Figure 9 below is examined it can be seen that the overall extension per unit length at depth y below the neutral axis is given by

$$\varepsilon_1 = \frac{y}{(d-x)}\varepsilon_s$$

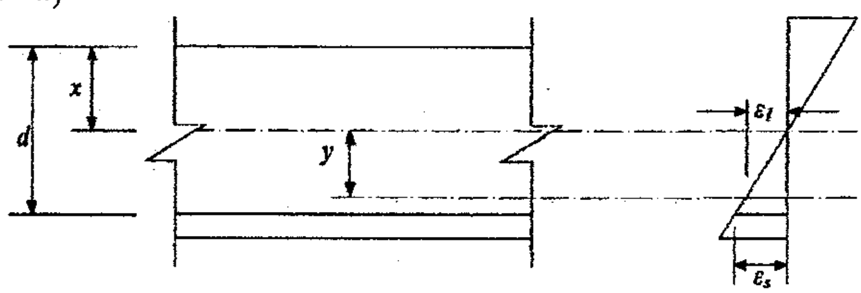

Figure 9: Bending strains

where ε_s is the average strain in the main reinforcement over the length considered, and may be assumed to be equal to f_s / E_s where f_s is the steel stress at the cracked sections. Hence, assuming any tensile strain of concrete between cracks as small, since full bond is never developed

$$\varepsilon_1 = \frac{y}{(d-x)}\frac{f_s}{E_s}$$

$$= \sum w$$

where $= \sum w$ = sum of crack widths per unit length at level y.

The actual width of individual cracks will depend on the number of cracks in this unit length the average number being given by length/average spacing where average spacing s_{av} = 1.67 a_{cr} for deformed bars; also $s_{av} \leq 1.67\ (h-x)$, the spacing of primary cracks.

Thus

$$\text{Average crack width } w_{av} = \frac{\Sigma w}{\text{Average number of cracks}}$$

$$= \varepsilon_1 s_{av}$$

Experimentally, if maximum crack width is taken as twice the average value, the chance of this being exceeded is about 1 in 100 hence for deformed reinforcing bars, the maximum likely crack width w_{max} at any level defined by y in a member will thus be given by

$$w_{max} = \varepsilon_1 2 s_{av}$$

$$= \varepsilon_1 3.33 a_{cr}$$

provided that the limit of $w_{max} = \varepsilon_1 3.33\ (h-x)$ based on the primary cracks is not exceeded.

The positions on a member where the surface crack widths will be greatest depend on the relative values of strain (ε_1) and the distance to a point of zero strain (a_{cr}). Despite the effects of bond slip adjacent to cracks, and the steel strain across cracks, the crack width at the surface of a reinforcing bar is very small and may be assumed to be zero. This may therefore be taken as a point of zero strain for the purposes of measuring a_{cr}. The neutral axis of the beam will also have zero strain and hence a_{cr} may also relate to this if appropriate.

Critical positions for maximum crack width will on a beam generally occur at the positions indicated in Figure 10 below. These occur when the distance to points of zero strain, that is, reinforcement surface of neutral axis, are as large as possible.

Positions 1 and 2 will have a maximum value of strain, while at position 3 although the strain is smaller, a_{cr} is considerably larger. The expression for w_{max} at any point may thus be expressed in the general form

maximum surface crack width at a point

= constant x distance to the surface of the nearest reinforcing bar or neutral axis x apparent tensile strain in the concrete at the level considered.

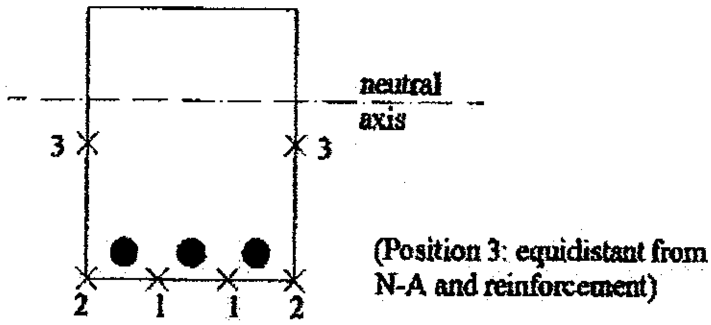

Figure 10: Critical crack positions

The expression for maximum surface crack width given in BS 8110 is basically of this form, with the constant based on a probability of the calculated value being exceeded of somewhat greater than 1 in 100. The expression is given as

$$w_{max} = \frac{3a_{cr}\varepsilon_m}{1+2\left(\dfrac{a_{cr}-c_{min}}{h-x}\right)}$$

where c_{min} is the minimum cover to the main reinforcement and ε_m is the average concrete strain and is based on ε_1 but allows for the stiffening effect of the cracked concrete in the tension zone ε_2. The value of ε_2 is given by an empirical expression

$$\varepsilon_2 = \frac{b_t(h-x)(a'-x)}{3E_sA_s(d-x)}$$

and

$$\varepsilon_m = \varepsilon_1 - \varepsilon_2$$

where b_t is the width of section at centroid of tensile steel and a' the distance from compressive face to the point at which crack is calculated. This expression allows for variations of steel stress between cracks, and results in correspondingly reduced maximum crack width estimates. A negative value of ε_m indicates that the section is uncracked.

5. ULTRASONIC PULSE VELOCITY TESTINGS

The measurement of the velocity of ultrasonic pulses as a means of testing materials was originally developed for assessing the quality and condition of concrete and the PUNDIT will undoubtedly be used predominately for this purpose. Figure 11 shows the picture of the equipment. In most of the applications it is necessary to measure the pulse velocity to a high degree of accuracy since relatively small changes in pulse velocity usually reflect relatively large changes in the condition of the concrete. For this reason it is important that care be taken to obtain the highest possible accuracy of both the transit time and the path length measurements since the pulse velocity measurement depends on both of these. Accuracy of transit time measurement can only be assured if good acoustic coupling between the transducer face and the concrete surface can be achieved. For a concrete surface formed by casting against steel or smooth timber shuttering, good coupling can readily be obtained if the surface is free from dust and grit and covered with a light or medium grease or suitable couplant. A wet surface presents no problem. If the surface is moderately rough, stiffer grease should be used but very rough surfaces require more elaborate preparation.

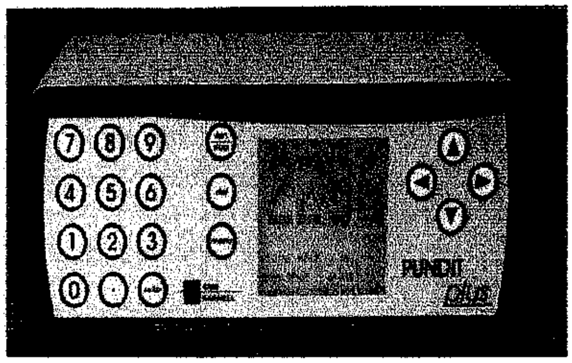

Figure 11: PUNDIT to measure UPV of concrete cube

5.1 Direct Method

When an ultrasonic pulse traveling through concrete meets a concrete-air interface, there is a negligible transmission of energy across this interface so that any air-filled crack or void lying directly between the transducers will obstruct the direct beam of ultrasound when the void has a projected area larger than the area of the transducer faces. The first pulse to arrive at the receiving transducer will have been diffracted around the periphery of the defect and the transit time will be longer than in similar concrete with no defect.

The arrangement for direct method is as shown in Figure 12, where it requires access to two surfaces. The transmitting and receiving transducers are placed on opposite surfaces of the concrete slab. This will give maximum sensitivity and provide a well-defined path length.

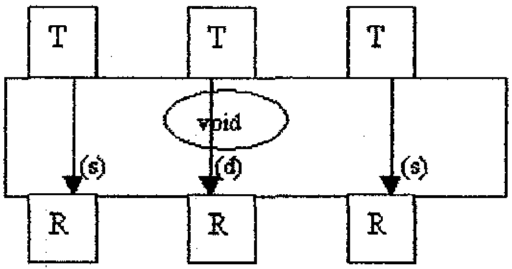

Figure 12: Void Detections using the Direct Method

5.2 Indirect Method

Performing UPV testing requires access to two surfaces, unless indirect (surface transmission) testing is to be done. Though indirect arrangement is least satisfactory upon sensitivity and defined path length, but it is more commonly used since direct method is not possible to use at most of the time. Figure 13 shows the indirect method for detecting void. The void depth can be estimated using the following equation:

$$t = \frac{x_0}{2}\sqrt{\frac{V_s - V_d}{V_s + V_d}} \qquad (1)$$

Where V_d is the pulse velocity in the defect concrete (km/s), V_s is the pulse velocity in the sound concrete (km/s) and t is the depth of the defect (mm), x_0 is the distance at which the change of slope occurs (mm).

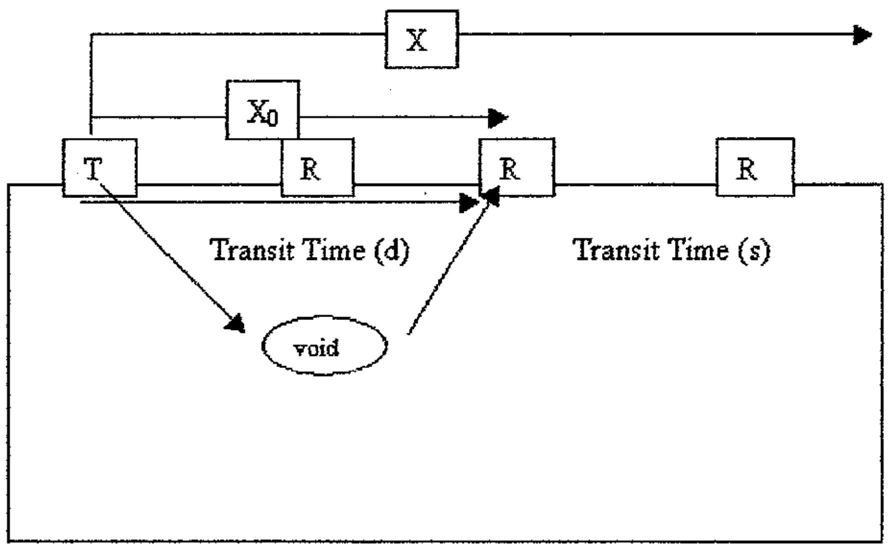

Figure 13: Void Detections using the Indirect Method.

In a UPV test, a piezoceramic source is electrically pulsed to generate ultrasonic waves, which travel in the structural element, and are sensed by the matching receiver on the opposite side of the test member. The waveform at the receiver is recorded (including the signal transmission start time) by the PC-based system. Knowing the travel distance and travel time, the ultrasonic compression wave velocity is then calculated. After the receiver output is recorded by the PC data acquisition system, the data can be analyzed. Three parameters are used in the interpretation of data:

1. Arrival of compression waves
2. Signal strength and
3. Distortion of the transmitted signal.

CHAPTER 4

RESULT AND DISCUSSION

1. VISUAL EXAMINATION

The site investigation is done during the early part of the study to observe the crack at the slabs. These are the recordings of observation of the concrete slabs:

Types of visual observation	**Yes**	**No**
Softening		√
Leaching matrix		√
Whitening of concrete		√
Rust stains		√
Discoloration		√
Flaking		√
Colour changes		√
Any exposed reinforcements		√
Crack Pattern		
Mesh pattern		√
Surface crazing		√
Have roughly uniform width	√	
Taper along the length		√
Pop-outs		√

Table 3: Crack observation checklist

The crack width cannot be measured because of lack of equipments at site. The visual observation is then transferred to the layout plan to do the crack mapping. Please refer to Appendix 2 (a) for the location of cracks at ground floor (clouded area) and Appendix 2 (b) for the crack mapping layout. The visual observation is according to Appendix 1. According to the visual observation at site, the crack is unidirectional and uniform. It cracks horizontally between grid 14-18 and from grid G-Af. The crack location is at the centre of the building which supposed to be the prayer hall. At the time when the crack is observed, only ground floor has been constructed. Since the crack occurs during construction, this shows that the crack is new. The crack is active at first when it starts to occur but after a while the cracks become dormant. The crack is active at first when it starts to occur but after a while the cracks become dormant. The crack only appears at the surface of the slab. By observation, the crack hair line is small and it is less than 0.3mm.

There is a public market nearby and the surrounding buildings are mainly shop lots consist of 4 to 5 floors. By interviewing some of the locals and engineers of the construction, there are no other cases such as this anywhere else nearby.

The building is constructed on marine clay soil type. The soil profile can be seen in Appendix 3 (a) and 3 (b). As can be seen in the soil profile, the subsurface ground condition at the site can be classified with the following layers: alluvial deposits and residual soil of Kenny Hill formation. The alluvial deposits consist of very soft to soft clay from GL 0 to GL 18 for BH3 and GL 3.5 to GL 21.5 at BH1A. The residual of Kenny Hill Formation underline the alluvial deposits layer throughout the side. The residual of Kenny Hill Formation consist of greyish brown to clayey silt with fine sand and traces of gravel below the soft clay where $N \geq 50$. Précised surveying has been done for 16 weeks to check any settlement of the ground but from the readings it shows that there is no significant ground movement at the site. So, the possibility of the crack to occur because of differential settlement can be ruled out. Unfortunately, the précised surveying report is confidential and cannot be released to other parties.

There is a possibility that this crack occurs because of plastic shrinkage. For this paper, the analysis is start by checking the maximum allowed thermal and shrinkage crack and flexural crack for three random slabs.

2. RESULTS AND DISCUSSION FROM CALCULATIONS

2.1 Reinforcement Checks and Shrinkage and Thermal Crack Calculation

2.1.1 Slab E-G /14-18

For analysis calculation from EsteemPlus 6.2.5.8 Software, please refer to Appendix 4 (a). Comparison between original reinforcement and analyzed reinforcement:

	Analyzed	Original	
M_{xx}	Y10 – 275	Y10 – 200	OK
M_{yy}	Y10 – 275	Y10 – 300	OK
M_{sy1}	Y10 – 200	Y10 – 200	OK
M_{sy2}	Y10 – 200	Y10 – 300	NOT OK
M_{sx1}	Y10 – 300	Y10 – 200	OK
M_{sx2}	Y10 – 300	Y10 – 300	OK

Table 4: Comparison of reinforcements for slab E-G/14-18

To eliminate the possibility that the crack is caused by design fault, the original reinforcement's spacing must be lesser or the same as the analyzed reinforcement. From this table, it can be seen that three of reinforcements are not suitable for the design of this slab. But the differences are not that big in terms of spacing but still can be considered as design fault. But nevertheless, the crack occurs at the early stage of the construction without utilising much loading. Thus, the possibility that the crack occurs because of design error can be ruled out. The plan view and cross-sections for slab E-G / 14-18 is at Appendix 6 (a).

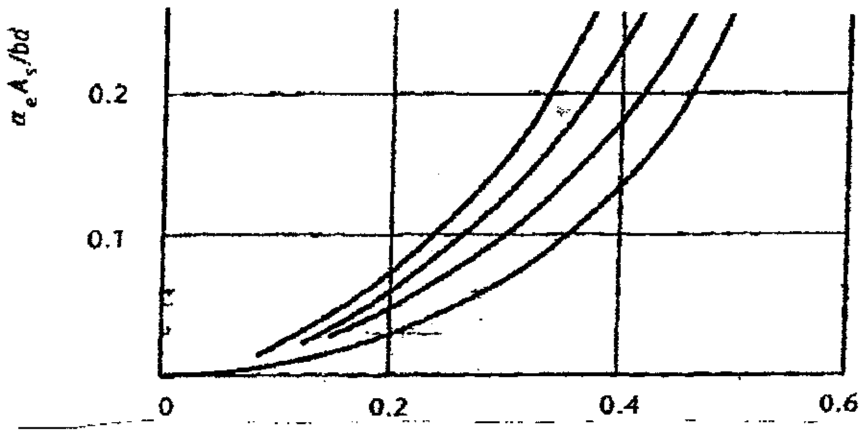

Figure 14: Neutral axis-depth for cracked rectangular sections – elastic behaviour

The calculation for thermal and shrinkage cracking is at Appendix 5 (a). The maximum crack width for shrinkage and thermal cracking is 0.10mm. The maximum crack width for flexural cracking will occur either at position 1 or 2 as indicated in Figure 15.

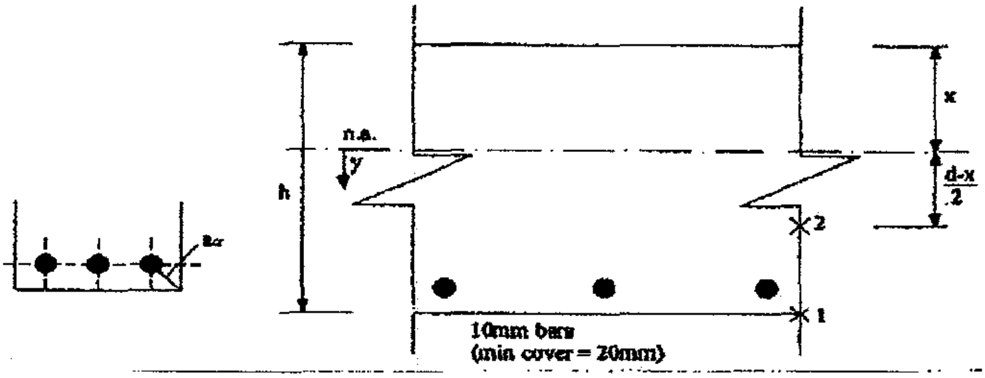

Figure 15: Cross-section and detail of reinforcement position

The maximum crack width of 0.10mm is therefore likely to occur at the bottom of the member, and the cracks are likely to be at an average spacing of 1.67 a_{cr} = 1.67 *x* 23.3 ≈ 39 mm at those positions. Cracks of similar width may occur on side faces at a spacing of approximately 1.67 *x* 44.2 ≈ 74 mm.

2.1.2 Slab K-M / 14-18

For calculation from EsteemPlus 6.2.5.8 software, please refer to Appendix 4 (b). Comparison between original reinforcement and analyzed reinforcement:

	Analyzed	Original	
M_{xx}	Y10 – 200	Y10 – 150	OK
M_{yy}	Y10 – 300	Y10 – 300	OK
M_{sy1}	Y10 – 150	Y10 – 150	OK
M_{sy2}	Y10 – 150	Y10 – 150	OK
M_{sx1}	Y10 – 300	Y10 – 150	OK
M_{sx2}	Y10 – 300	Y10 – 150	OK

Table 5: Comparison of reinforcements for slab K-M / 14-18

To eliminate the possibility that the crack is caused by design fault, the original reinforcement's spacing must be lesser or the same as the analyzed reinforcement. From this table, it can be seen that two of the reinforcements are not suitable for the design of this slab. But nevertheless, the crack occurs at the early stage of the construction without utilising much loading. Thus, the possibility that the crack occurs because of design error can be ruled out. The plan view and cross-sections for slab K-M / 14-18 are at Appendix 6 (b).

The calculations for thermal and shrinkage cracking and flexural cracking are at Appendix 5 (b). The maximum crack width for shrinkage and thermal cracking is 0.10mm. The maximum crack width will occur either at position 1 or 2 as indicated in Figure 10. The maximum crack width of 0.12mm is therefore likely to occur at the bottom of the member, and the cracks are likely to be at an average spacing of 1.67 $a_{cr} = 1.67 \times 23.3 \approx 39$ mm at those positions. Cracks of similar width may occur on side faces at a spacing of approximately $1.67 \times 36.6 \approx 61$ mm.

2.1.3 Slab W1-Y / 14-18

For calculation from EsteemPlus 6.2.5.8 software, please refer to Appendix 4 (c). Comparison between original reinforcement and analyzed reinforcement:

	Analyzed	**Original**	
M_{xx}	Y10 – 250	Y10 – 200	OK
M_{yy}	Y10 – 275	Y10 – 300	NOT OK
M_{sy1}	Y10 – 175	Y10 – 200	NOT OK
M_{sy2}	Y10 – 175	Y10 – 300	NOT OK
M_{sx1}	Y10 – 300	Y10 – 200	OK
M_{sx2}	Y10 – 300	Y10 – 300	OK

Table 6: Comparison of reinforcements for slab W1-Y / 14-18

To eliminate the possibility that the crack is caused by design fault, the original reinforcement's spacing must be lesser or the same as the analyzed reinforcement. From this table, it can be seen that one of the reinforcements are not suitable for the design of this slab. But nevertheless, the crack occurs at the early stage of the construction without utilising much loading. Thus, the possibility that the crack occurs because of the design error can be ruled out. The plan view and cross-sections for slab Ae-Ae1 / 14-18 are at Appendix 6 (c).

The calculations for thermal and shrinkage cracking and flexural cracking are at Appendix 5 (c). The maximum crack width for shrinkage and thermal cracking is

0.10 mm. The maximum crack width will occur either at position 1 or 2 as indicated in Figure 10. The maximum crack width of 0.11 mm is therefore likely to occur at the bottom of the member, and the cracks are likely to be at an average spacing of 1.67 a_{cr} = 1.67 *x* 23.3 ≈ 39 mm at those positions. Cracks of similar width may occur on side faces at a spacing of approximately 1.67 *x* 4.83 ≈ 81 mm.

2.2 Flexural Cracking

Calculation of flexural cracking is done for the slabs from Grid C-Ae1/14-18 with the help of Microsoft Excel in which shown in the Appendix 6 and 7. Comparison between two different diameter bars (10mm and 12mm) is to see whether increasing the bar diameter can actually overcome flexural cracking. From the result in the table below, we can see that the flexural fails from E-Y/14-18 (red indicates that the slab fails) which coincides with the actual crack on the slab which occurs at E-Y/14-18. The limitation for this calculation is 0.20mm for flexural cracking. When calculating again using 12mm diameter bars, none of the slabs failed and thus it shows that increasing the bar diameter probably solves the problem of the cracking.

Slab Location	10mm diameter bar	12mm diameter bar
Ad-Ae/14-18	0.09	0.07
Ae1-Af/14-18	0.14	0.14
Ae-Ae1/14-18	0.14	0.07
C-D/14-18	0.09	0.06
D-E/14-18	0.05	0.05
E-G/14-18	**0.25**	0.17
G-J/14-18	**0.24**	0.17
J-K/14-18	**0.24**	0.17
K-M/14-18	**0.25**	0.17
M-P/14-18	**0.25**	0.17
P-R/14-18	**0.24**	0.17
R-T/14-18	**0.24**	0.17
T-V/14-18	**0.26**	0.17
V-W1/14-18	**0.29**	0.18
W1-Y/14-18	**0.24**	0.18
Y-Ad/14-15	**0.22**	-0.05
Y-Ad/17-18	0.12	-0.05
Y-Z/15-15A	-0.03	-0.02
Y-Z/15A-16A	-0.04	-0.05
Y-Z/16A-17	0.03	-0.02
Z-Ad/15-16	0.03	-0.05
Z-Ad/16-17	0.03	-0.05

Table 7: Calculated crack width for slabs C-Ae1/14-18 of 10mm and 12mm diameter bars

2.3 Ultra Pulse Velocity Test

The result for Ultra Pulse Velocity test is as shown below:

DIRECT METHOD	Cube A	3897.7m/s	**Average=** 3917.8 m/s (3.9 km/s)
	Cube B	3927.8m/s	
	Cube C	3927.8m/s	
INDIRECT METHOD	Cube A	3791.0m/s	**Average=** 3917.0 m/s (3.9 km/s)
	Cube B	4042.4m/s	
	Cube C	3917.7m/s	

Table 8: Results from Ultra Pulse Velocity test

The result from direct method and indirect method is approximately the same and are rounded to 3.9km/s. The result is then transferred to P. Turgut's chart to plot and find the concrete's strength.

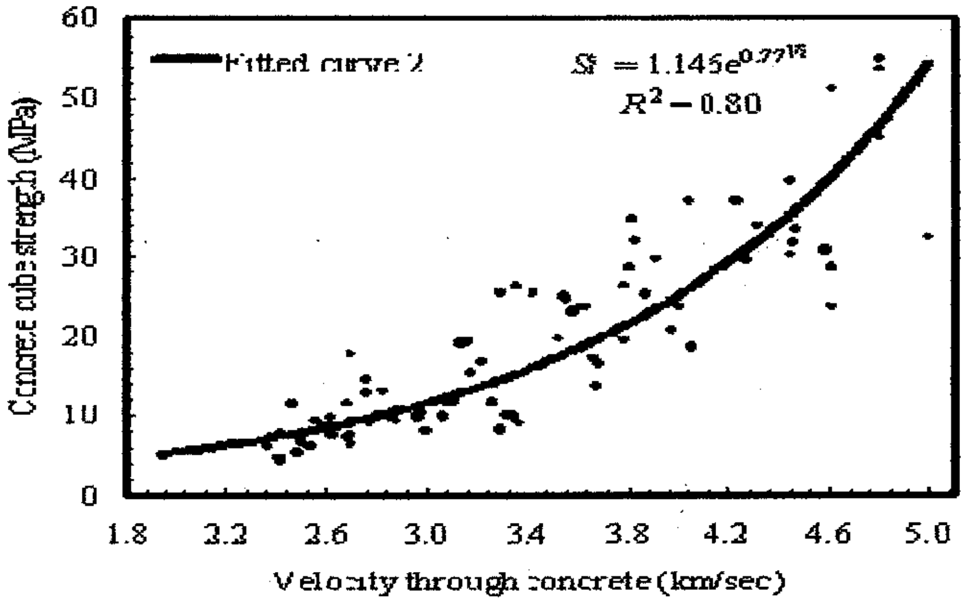

Figure 16: Relationship between concrete strength and UPV in existing reinforced concrete structures

Plotting 3.9km/s in this chart, we can see that its concrete cube strength is 23.5MPa. The concrete cube strength used to design this building is actually 30MPa. Thus it is a possibility that insufficient concrete strength could be the cause of crack in Klang Mosque.

CHAPTER 5

CONCLUSION

There are five methods used to find out the possible causes of cracks in Klang Mosque which are:

- Visual Observation
- Check detailing of reinforcement using EsteemPlus
- Shrinkage and thermal cracking calculation
- Flexural cracking
- Ultra Pulse Velocity test

The possible causes of cracks are as follows:

(i) *Visual Observation* - From the visual observation, the author found out that the pattern (long, around 38m in length), its crack width (around 2-4mm) and it only appear on the surface only which is the tension zone.

(ii) *Check detailing of reinforcement using EsteemPlus* - After checking the detailing of reinforcement, it is found that some of the reinforcements are not enough compared to the analysis in the EsteemPlus. This shows that reinforcement detailing could be one of the possible causes of crack there.

(iii) *Shrinkage and thermal cracking calculation* - By checking shrinkage and thermal cracking calculation, the calculated crack width is less than allowable crack width. Thus shrinkage of concrete is not the cause of crack in Klang Mosque.

(iv) *Flexural cracking* – The flexural cracking calculation done shows that the slabs from E-Y/14-18 are all exceed the maximum allowable crack width of 0.2mm for 10mm diameter bars but passed for 12mm bars. This shows that flexural cracking is another cause of cracks and the designers did not take into consideration the calculation of flexural cracking in their design.

(v) *Ultra Pulse Velocity Test* – This test is to check the concrete strength used for the construction of the building. The concrete strength gotten from the test is 23.5 MPa which is much lesser than the concrete strength used in the design which is 30 MPa. This shows that another cause for this cracking is the poor construction practice at site.

Conclusively, there are two possible causes of cracks that occur in Klang Mosque which are design failure and also poor construction practices. Both are human errors and are common factors in construction site anywhere. Therefore, to solve this problem, mitigation measures must be done so that no further cracks can occur at Klang Mosque site.

1. Mitigation Measures

In order to mitigate the cracks occurred, there is an economical and easy way to do it which does not involve demolishing the whole area and redo the construction again with another design. The method is by demolishing the concrete at the tension zone. After that, add dowel bars at the demolished part for every 1-2m. Then, they can fix conventional reinforcement (in the form of mesh) under the reinforcements and dowel bars and securing it in place by the use of sprayed-concrete techniques.

CHAPTER 6

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CHAPTER 7

APPENDICES

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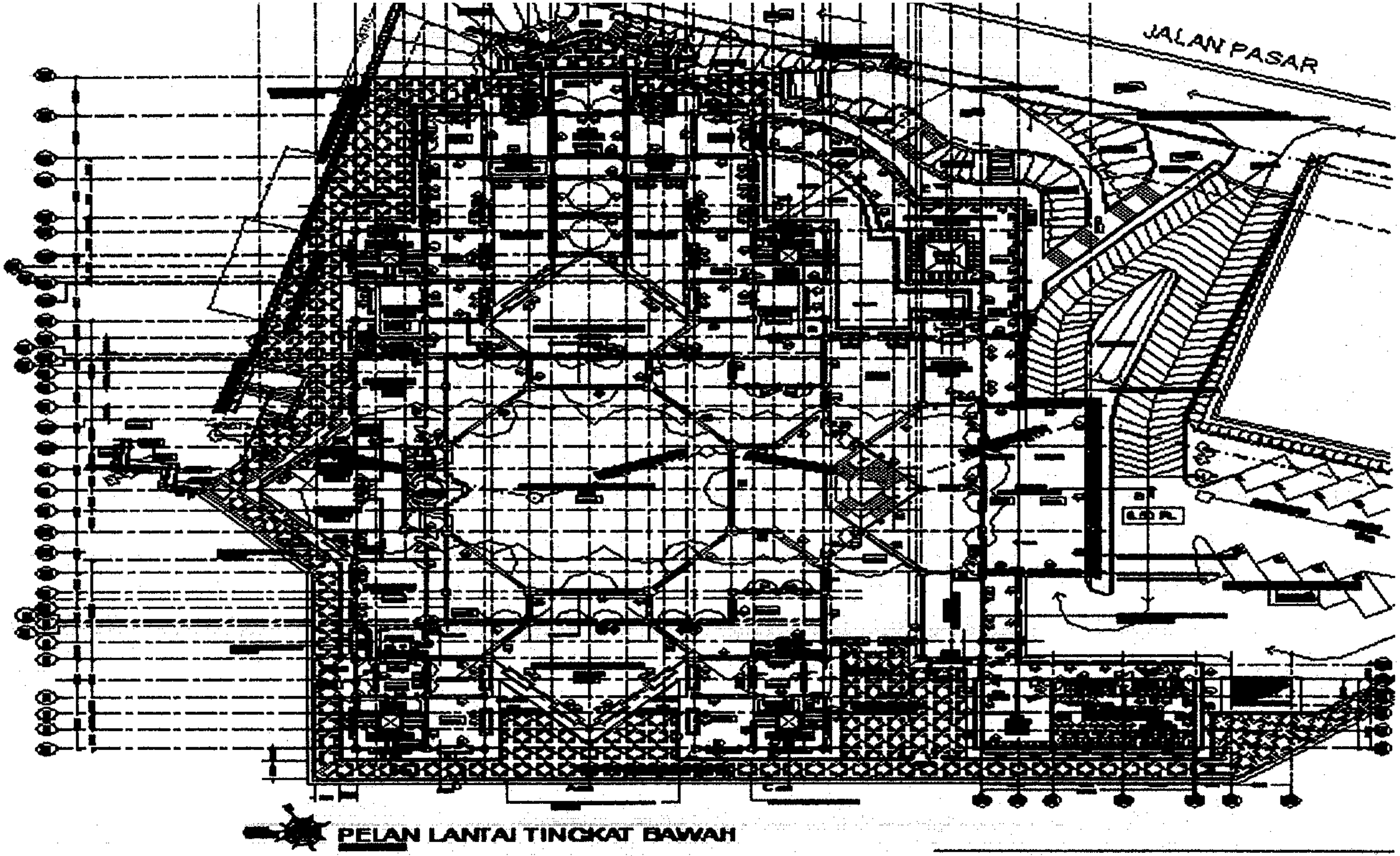
Appendix 9: Public Assembly Occupancy Class (Halls, Auditoria, Restaurants, Museums, Libraries, Non-Residential Clubs, Theatres, Broadcasting Studios, Grandstands) (Taken from BS 6399: Part 1: 1984)

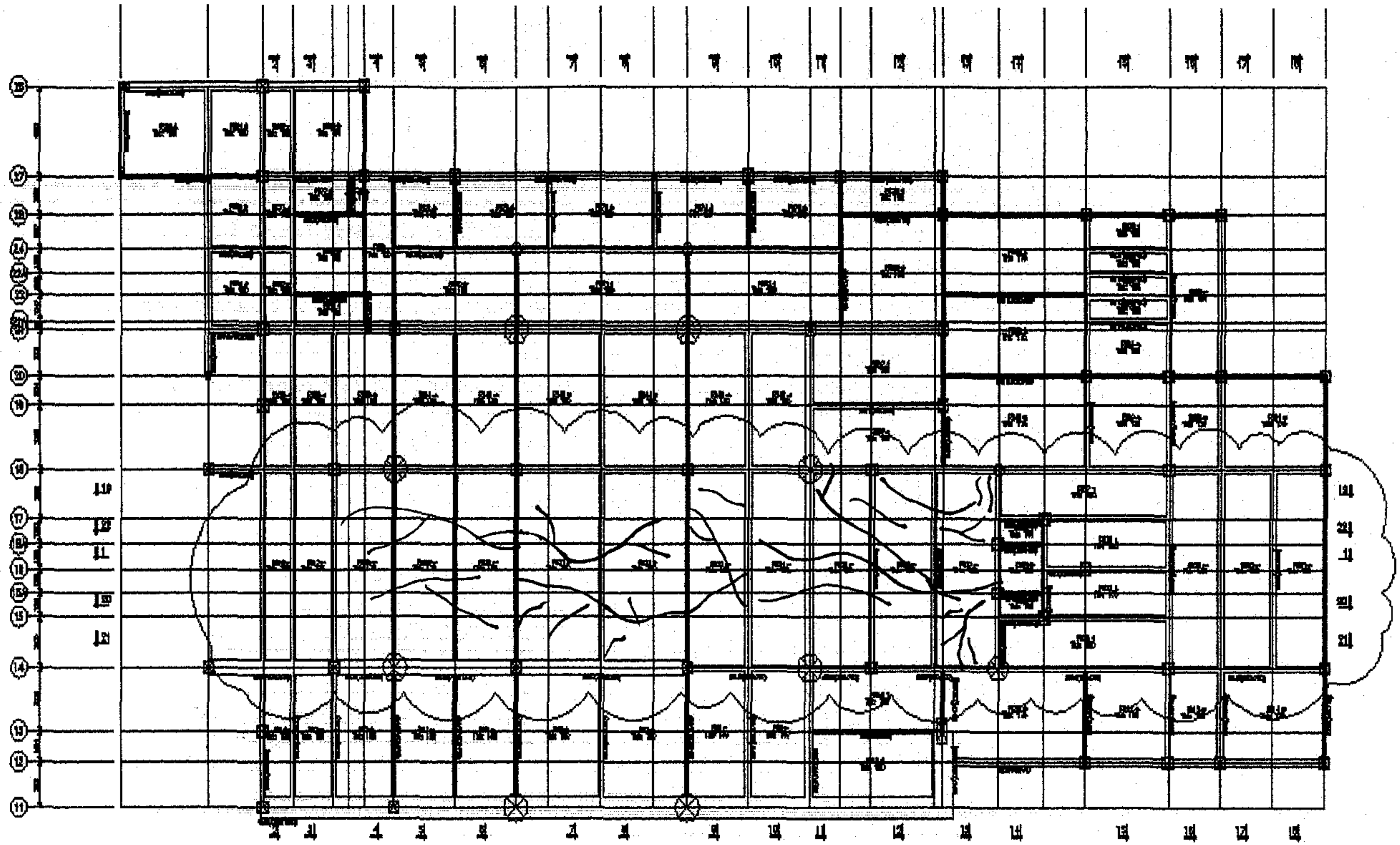
Summary of Defects Occurring During Construction

Symptom	Cause	Prevention	Remedy
Cracks in horizontal surface, as concrete stiffens or very soon thereafter.	Plastic shrinkage: rapid drying of surface	Shelter during placing. Cover as early as possible. Use air-entrainment.	Seal by brushing in cement or low viscosity polymer.
Cracks form above ties, reinforcement etc., or at arisses. Especially in deep lifts.	Plastic settlement: concrete continues to settle after starting to stiffen.	Charge mix design. Use air-entrainment.	Recompact upper part of concrete while still plastic. Seal cracks after concrete has hardened.
Cracks in thick sections, occurring as concrete cools.	Restrained thermal contraction.	Minimize restraint to contraction. Delay cooling until concrete has gained strength.	Seal cracks.
Blowholes in form faces of concrete.	Air or water trapped against formwork: Inadequate compaction. Unsuitable mix design. Unsuitable release agent.	Improve vibration. Change mix design. Use appropriate release agent. Use absorbent formwork.	Fill with polymer modified fine mortar.
Voids in concrete.	Honeycombing: Inadequate compaction. Grout loss.	Improve compaction. Reduce maximum size of aggregate. Prevent leakage of grout.	Cut out and make good. Inject resin.
Erosion of vertical surfaces, in vertical streaky pattern.	Scouring: Water moving upwards against form face.	Change mix design, to make more cohesive or reduce water content.	Rub in polymer modified fine mortat.
Colour variations.	Variations in mix proportions, curing conditions, materials, characteristics of form face, vibration, release agent. Leakage of water from formwork.	Ensure uniformity of all relevant factors. Prevent leakage from formwork.	Apply surface coating.
Powdery formed surface.	Surface retardation, caused by sugars in certain timbers.	Change form material. Seal surface of	Generally, none required.

		formwork. Apply limewash to form face before first few uses.	
Rust-strains	Pyrites in aggregates. Rain streaking from unprotected steel. Rubbish in formwork. Ends of wire ties turned out.	Avoid contaminated aggregates. Protect exposed steel. Clean forms thoroughly. Turn ends of ties inwards.	Clean with dilute acid or sodium citrate/sodium dithionite. Apply surface coating.
Plucked surface	Insufficient release agent. Careless removal of formwork.	More care in applications of release agent and removal of formwork.	Rub in fine mortar, or patch as for spalled concrete.
Lack of cover to reinforcement.	Reinforcement moved during placing of concrete, or badly fixed. Inadequate tolerances in detailing.	Provide better support for reinforcement. More accurate steel fixing. Greater tolerances in detailing.	Apply polymer modified cement and sand rendering. Apply protective coating.



Location of cracks at Ground Floor



Crack mapping layout

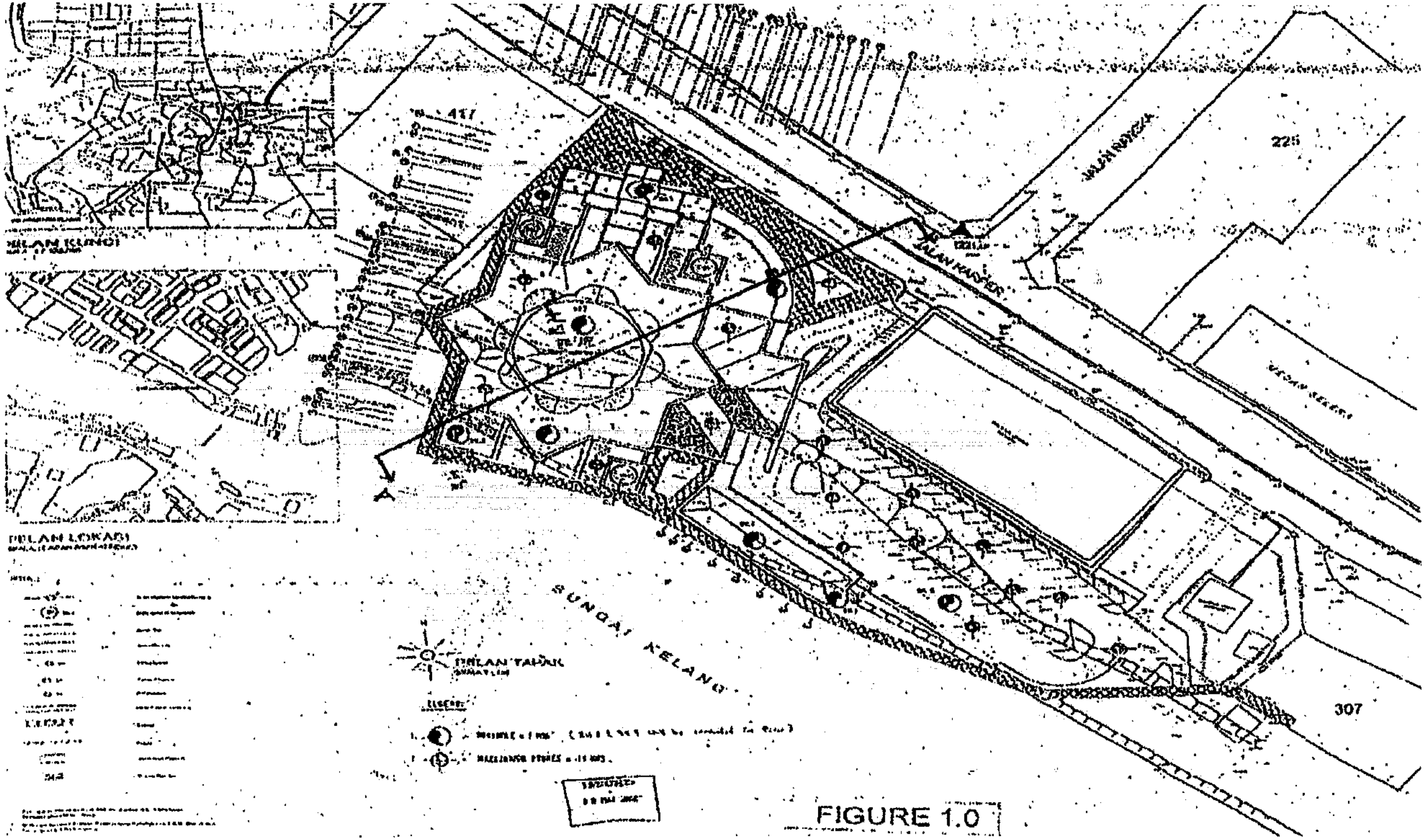
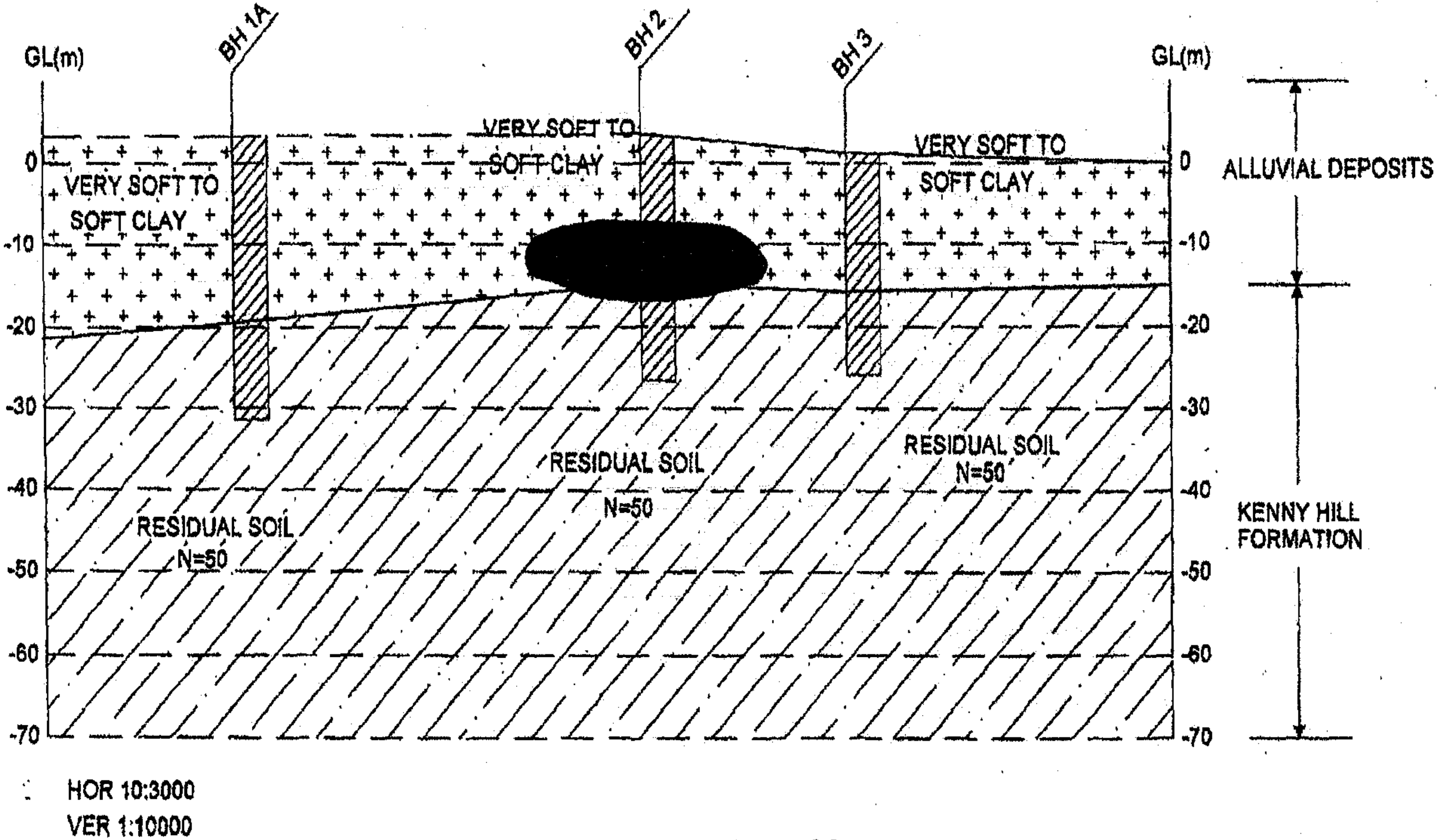


FIGURE 1.0

Orientation of soil profile at the site of Klang Mosque



Soil profile at the site of Klang Mosque

Location: 14-18 / E-G

Dimensions		Thickness	Imposed Live Load, ILL	Imposed Dead Load, IDL
X	Y			
3600 mm	10000 mm	125 mm	5.0 kN/m^2	1.7 kN/m^2

Total Dead Load = Self Weight + Imposed Dead Load
= Thickness x Concrete Density / 1000 + IDL
= 125 x 24 / 1000 + 1.70
= 4.70

Total factored load, W_u = 1.40 x 4.70 + 1.60 x 5.00 = 14.58 kN/m^2
Total factored load x l_x x l_x = W_u x L_x x L_x
= WL = 14.58 x 3.6 x 3.6
= 188.96 kNm/m width

Long / Short span-ratio, l_y/l_x = 10000/3600 = 2.78

$l_y/l_x > f_2$ → Increase moment coefficients by: 1 + (min (2.78, 8)-2)/8 x 0.15 = 1.01458
To allow for one-way slab, adjust the short span moment coefficients by 1.01458 times

Case 1: All the four edges are continuous
Span and support coefficients:
$B_x = 0.055$, $B_y = 0.024$, $B_{sx} = 0.073$, $B_{sy} = 0.032$

Moment based on the above coefficients (before redistribution):
Short span moment, $M_x = B_x$ x WL = 0.055 x 188.96 = 10.39
Long span moment, $M_y = B_y$ x WL = 0.024 x 188.96 = 4.53
Support short span moment, $M_{sx} = B_{sx}$ x WL = 0.073 x 188.96 = 13.86
Support long span moment, $M_{sy} = B_{sy}$ x WL = 0.032 x 188.96 = 6.05

Summary of Moment, Steel Area Required, Rebar Provided:

	M_{xx}	M_{yy}	M_{sy1}	M_{sy2}	M_{sx1}	M_{sx2}
Moment	10.39	4.53	13.86	13.86	6.05	6.05
Area	271	188	366	366	188	188
Rebar	T10-275	T10-275	T10-200	T10-200	T10-300	T10-300

Deflection Check:
Dimensions X: 3600 < Y = 10000 AND bottom of bottom (BB) rebar is spanning X-direction:
So effective depth, d = Thickness – cover – $X_{Rebar}/2$
= 125 – 20 – 10/2
= 100.0 mm

Span/depth's ratio, $A_f = l/d$
= 3600 / 100.0
= 36.0

Basic Span/depth's ration, B_r = 26.0
$A = 5 f_y A_{s,req} / (8 A_{s,prov})$

$= 5 \times 460 \times 271 / (8 \times 286)$
$= 272.5$
$B = 120 \times [0.9 + M / (b \times d^2)]$
$= 120 \times [0.9 + 10.39 \times 1000 / (100 \times 100)]$
$= 232.7$
Modification Factor, $MF = 0.55 + (477 - A) / B$
$= 0.55 + (477 - 272.5) / 232.7$
$= 1.43$
Slab deflection ratio $= MF \times B_r / A_r$
$= 1.43 \times 26.0 / 36$
$= 1.03$

Ratio ≥ 1.0: Deflection check PASSED

Location: 14-18 / K-M

Dimensions		Thickness	Imposed Live Load, ILL	Imposed Dead Load, IDL
X	Y			
5000 mm	10000 mm	150 mm	5.00 kN/m^2	1.70 kN/m^2

Total Dead Load = Self Weight + Imposed Dead Load
= Thickness x Concrete Density / 1000 + IDL
= 150 x 24 / 1000 + 1.70
= 5.30
Total factored load, W_u = 1.40 x 5.30 + 1.60 x 5.00 = 15.42 kN/m^2
Total factored load x l_x x l_x = W_u x L_x x L_x
= WL = 15.42 x 5 x 5
= 385.50 kNm/m width

Long / Short span-ratio, l_y/l_x = 10000/5000 = 2.00

Case 1: All the four edges are continuous
Span and support coefficients:
B_x = 0.048, B_y = 0.024, B_{sx} = 0.063, B_{sy} = 0.032

Moment based on the above coefficients (before redistribution):
Short span moment, $M_x = B_x$ x WL = 0.048 x 385.50 = 18.32
Long span moment, $M_y - B_y$ x WL = 0.024 x 385.50 = 9.25
Support short span moment, $M_{sx} = B_{sx}$ x WL = 0.063 x 385.50 = 24.43
Support long span moment, $M_{sy} = B_{sy}$ x WL = 0.032 x 385.50 = 12.34

Summary of Moment, Steel Area Required, Rebar Provided:

	M_{xx}	M_{yy}	M_{sy1}	M_{sy2}	M_{sx1}	M_{sx2}
Moment	18.32	9.25	24.43	24.43	12.34	12.34
Area	384	225	521	521	254	254
Rebar	T10-200	T10-300	T10-150	T10-150	T10-300	T10-300

Deflection Check:
Dimensions X: 5000 < Y = 10000 AND bottom of bottom (BB) rebar is spanning X-direction:
So effective depth, d = Thickness – cover – $X_{Rebar}/2$
= 150 – 20 – 10/2
= 125.0 mm
Span/depth's ratio, $A_f = l/d$
= 5000 / 125.0
= 40.0
Basic Span/depth's ration, B_r = 26.0
$A = 5 f_y A_{s,req} / (8 A_{s,prov})$
= 5 x 460 x 384 / (8 x 393)
= 281.0
$B = 120 \times [0.9 + M / (b \times d^2)]$

$= 120 \times [0.9 + 18.32 \times 1000 / (125 \times 125)]$
$= 248.7$

Modification Factor, $MF = 0.55 + (477 - A) / B$
$= 0.55 + (477 - 281) / 248.7$
$= 1.34$

Slab deflection ratio $= MF \times B_r / A_r$
$= 1.34 \times 26.0 / 40.00$
$= 0.87$

Area after deflection check = 477

$A = 5 f_y A_{s,req} / (8 A_{s,prov})$
$= 5 \times 460 \times 384 / (8 \times 477)$
$= 231.2$

Modification Factor, $MF = 0.55 + (477 - A) / B$
$= 0.55 + (477 - 231.2) / 248.7$
$= 1.54$

Slab deflection ratio $= MF \times B_r / A_r$
$= 1.54 \times 26.0 / 40.00$
$= 1.00$

Deflection governs the design, consider option to increase depth!
Ratio ≥ f_1: Deflection check PASSED

Deflection governs the design, Steel Area Provided After Deflection Check:
Steel Area = 477; Use T10-150

Location: 14-18 / W1-Y

Dimensions		Thickness	Imposed Live Load, ILL	Imposed Dead Load, IDL
X	Y			
3700 mm	10000 mm	125 mm	5.00 kN/m^2	1.70 kN/m^2

Total Dead Load = Self Weight + Imposed Dead Load
= Thickness x Concrete Density / 1000 + IDL
= 125 x 24 / 1000 + 1.70
= 4.70

Total factored load, W_u = 1.40 x 4.70 + 1.60 x 5.00 = 14.58 kN/m^2

Total factored load x l_x x l_x = W_u x L_x x L_x
= WL = 14.58 x 3.7 x 3.7
= 199.6 kNm/m width

Long / Short span-ratio, l_y/l_x = 10000/3700 = 2.7

$l_y/l_x > f_2$ → Increase moment coefficients by: 1 + (min (2.7, 8)-2)/8 x 0.15 = 1.01318
To allow for one-way slab, adjust the short span moment coefficients by 1.01318 times

Case 5: Two short edges discontinuous
Span and support coefficients:
B_x = 0.058, B_y = 0.034, B_{sx} = 0.078, B_{sy} = 0

Moment based on the above coefficients (before redistribution):
Short span moment, M_x = B_x x WL = 0.058 x 199.6 = 11.66
Long span moment, M_y = B_y x WL = 0.034 x 199.6 = 6.79
Support short span moment, M_{sx} = B_{sx} x WL = 0.078 x 199.6 = 15.54

Summary of Moment, Steel Area Required, Rebar Provided:

	M_{xx}	M_{yy}	M_{sy1}	M_{sy2}	M_{sx1}	M_{sx2}
Moment	11.66	6.79	15.54	15.54	0	0
Area	305	195	414	414	188	188
Rebar	T10-250	T10-275	T10-175	T10-175	T10-300	T10-300

Deflection Check:
Dimensions X: 3700 < Y = 10000 AND bottom of bottom (BB) rebar is spanning X-direction:
So effective depth, d = Thickness – cover – $X_{Rebar}/2$
= 125 – 20 – 10/2
= 100.0 mm

Span/depth's ratio, A_f = l/d
= 3700 / 100.0
= 37

Basic Span/depth's ratio, B_r = 26.0
$A = 5 f_y A_{s,req} / (8 A_{s,prov})$
= 5 x 460 x 305 / (8 x 314)

$= 279.3$

$B = 120 \times [0.9 + M / (b \times d^2)]$

$= 120 \times [0.9 + 11.66 \times 1000 / (100 \times 100)]$

$= 247.9$

Modification Factor, $MF = 0.55 + (477 - A) / B$

$= 0.55 + (477 - 279.3) / 247.9$

$= 1.35$

Slab deflection ratio $= MF \times B_r / A_r$

$= 1.35 \times 26.0 / 37$

$= 0.95$

Area after deflection check = 337

$A = 5 f_y A_{s,req} / (8 A_{s,prov})$

$= 5 \times 460 \times 305 / (8 \times 337)$

$= 260.6$

Modification Factor, $MF = 0.55 + (477 - A) / B$

$= 0.55 + (477 - 260.6) / 247.9$

$= 1.42$

Slab deflection ratio $= MF \times B_r / A_r$

$= 1.42 \times 26.0 / 37.00$

$= 1.00$

Deflection governs the design, consider option to increase depth!
Ratio $\geq f_1$: Deflection check PASSED

Deflection governs the design, Steel Area Provided After Deflection Check:
Steel Area = 337; Use T10-225

Calculation of Shrinkage and Thermal Crack Widths for Slab 14-18 / E-G

Design assumptions:

Drying shrinkage strain, ε_{sh} = 50 microstrain
Temperature drop, T = 20°C
Three-day ultimate tensile strength of concrete, f_t = ultimate average bond stress, f_b = 1.5 N/mm^2
Modulus of elasticity of concrete, E_c = 10kN/mm^2
Coefficient of thermal expansion for mature concrete, α_c = 12 microstrain/°C
Characteristic yield strength of reinforcement, f_y = 460 N/mm^2
Modulus of elasticity of reinforcement, E_s = 200 kN/mm^2

Critical steel ratio, $r_{crit} = (f_t/f_y) = 1.5 / 460 = 0.33\%$

$$= \frac{0.33}{100} x 125 x 1000$$

$$= 412.5 \text{ mm}^2\text{/m}$$

This should be conveniently provided as 10mm bars at 200mm centres in each face of the member (393mm^2/m). This is the same as in the real design so the same value will be used. For this reinforcement, the maximum crack spacing is:

$$s_{\max} = \frac{f_t \Phi}{2\left(\frac{A_s}{A_c}\right) f_b} = \frac{1.5x10}{2x\frac{393x1.5}{125000}}$$

$= 1590$mm

Since the minimum spacing is given by one-half of this value, the average spacing will be $s_{av} = 0.75 \times 1590 = 1193$mm

The maximum crack width corresponds to s_{max} and is given by

$\omega_{max} = s_{max} [\, R\,(\varepsilon_{sh} + T\alpha_c) - ½\, \varepsilon_{ult}]$

where ultimate tensile strain for the concrete

$$\varepsilon_{ult} = \frac{f_t}{E_c} = \frac{1.5}{10x10^3} = 150 microstrain$$

Therefore assuming $R = 0.5$ (full restraint)

$\omega_{max} = 1590\ [0.5\ (50 + 20\ (12)) - ½\ (150)] \times 10^{-6} = 0.11$mm

Calculation of Shrinkage and Thermal Crack Widths for Slab 14-18 / K-M

Design assumptions:

Drying shrinkage strain, ε_{sh} = 50 microstrain
Temperature drop, T = 20°C
Three-day ultimate tensile strength of concrete, f_t = ultimate average bond stress, f_b = 1.5 N/mm^2
Modulus of elasticity of concrete, E_c = 10kN/mm^2
Coefficient of thermal expansion for mature concrete, α_c = 12 microstrain/°C
Characteristic yield strength of reinforcement, f_y = 460 N/mm^2
Modulus of elasticity of reinforcement, E_s = 200 kN/mm^2

Critical steel ratio, $r_{crit} = (f_t/f_y) = 1.5 / 460 = 0.33\%$

$$= \frac{0.33}{100} x150x1000$$

$$= 495 \text{ mm}^2/\text{m}$$

This should be conveniently provided as 10mm bars at 175mm centres in each face of the member (449mm^2/m). For the original design, the slab's reinforcement is 10mm bars at 150mm centers in each face of the member (524mm^2/m). For this reinforcement, the maximum crack spacing is:

$$s_{max} = \frac{f_t \Phi}{2\left(\frac{A_s}{A_c}\right) f_b} = \frac{1.5x10}{2x\frac{524x1.5}{150000}}$$

$$= 1431\text{mm}$$

Since the minimum spacing is given by one-half of this value, the average spacing will be s_{av} = 0.75 x 1431 = 1073mm

The maximum crack width corresponds to s_{max} and is given by

$\omega_{max} = s_{max} \left[R(\varepsilon_{sh} + T\alpha_c) - \frac{1}{2}\varepsilon_{ult}\right]$

where ultimate tensile strain for the concrete

$$\varepsilon_{ult} = \frac{f_t}{E_c} = \frac{1.5}{10x10^3} = 150 microstrain$$

Therefore assuming R = 0.5 (full restraint)

ω_{max} = 1431 [0.5 (50 + 20 (12)) – ½ (150)] x 10^{-6} = 0.10mm

Calculation of Shrinkage and Thermal Crack Widths for Slab 14-18 / W1-Y

Design assumptions:

Drying shrinkage strain, ε_{sh} = 50 microstrain
Temperature drop, T = 20°C
Three-day ultimate tensile strength of concrete, f_t = ultimate average bond stress, f_b = 1.5 N/mm^2
Modulus of elasticity of concrete, E_c = 10kN/mm^2
Coefficient of thermal expansion for mature concrete, α_c = 12 microstrain/°C
Characteristic yield strength of reinforcement, f_y = 460 N/mm^2
Modulus of elasticity of reinforcement, E_s = 200 kN/mm^2

Critical steel ratio, $r_{crit} = (f_t/f_y) = 1.5 / 460 = 0.33\%$

$$= \frac{0.33}{100} x125x1000$$

$$= 413 \text{ mm}^2/\text{m}$$

This should be conveniently provided as 10mm bars at 200mm centres in each face of the member (524mm^2/m). For the original design, the slab's reinforcement is 10mm bars at 150mm centers in each face of the member (524mm^2/m). For this reinforcement, the maximum crack spacing is:

$$s_{\max} = \frac{f_t \Phi}{2\left(\frac{A_s}{A_c}\right) f_b} = \frac{1.5x10}{2x\frac{524x1.5}{150000}}$$

$$= 1431 \text{mm}$$

Since the minimum spacing is given by one-half of this value, the average spacing will be s_{av} = 0.75 x 1431 = 1073mm

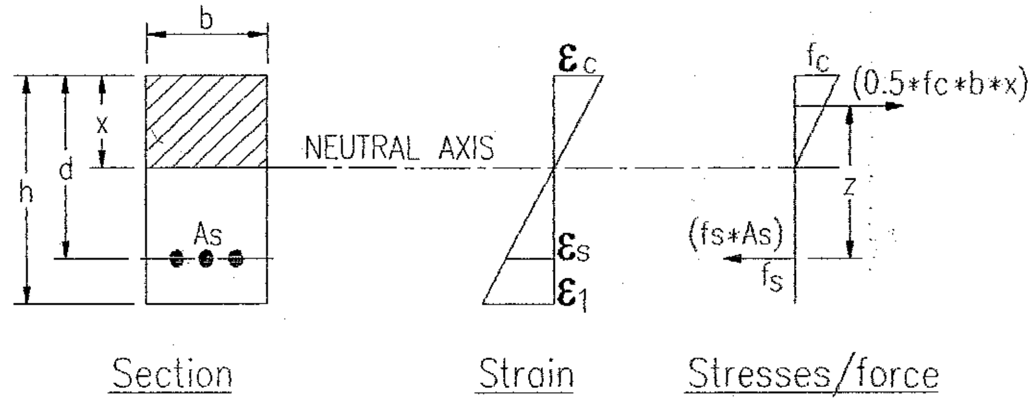
The maximum crack width corresponds to s_{max} and is given by
$\omega_{max} = s_{max} [R (\varepsilon_{sh} + T\alpha_c) - ½ \varepsilon_{ult}]$
where ultimate tensile strain for the concrete

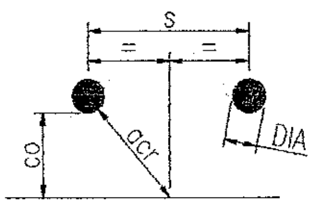
$$\varepsilon_{ult} = \frac{f_t}{E_c} = \frac{1.5}{10x10^3} = 150 microstrain$$

Therefore assuming R = 0.5 (full restraint)
ω_{max} = 1431 [0.5 (50 + 20 (12)) – ½ (150)] x 10^{-6} = 0.10mm

Appendix 6: Flexural Cracking Calculation for 10mm diameter bar

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	7.8	KNm

‹LATIONS

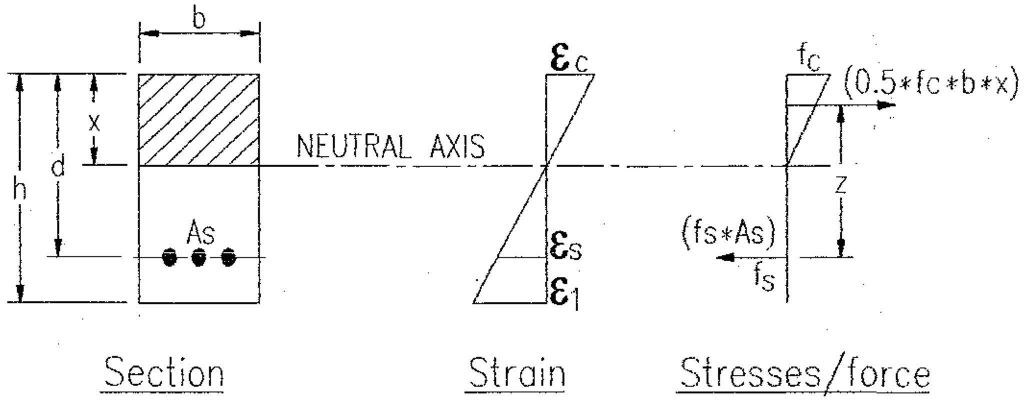
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	256	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	4.80	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001612	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1-\varepsilon_2$ =	0.000636	

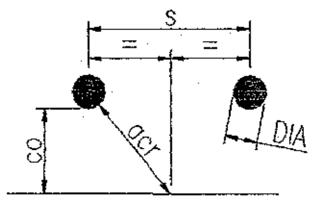
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.09**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Ae1-Af/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	12.2	KNm

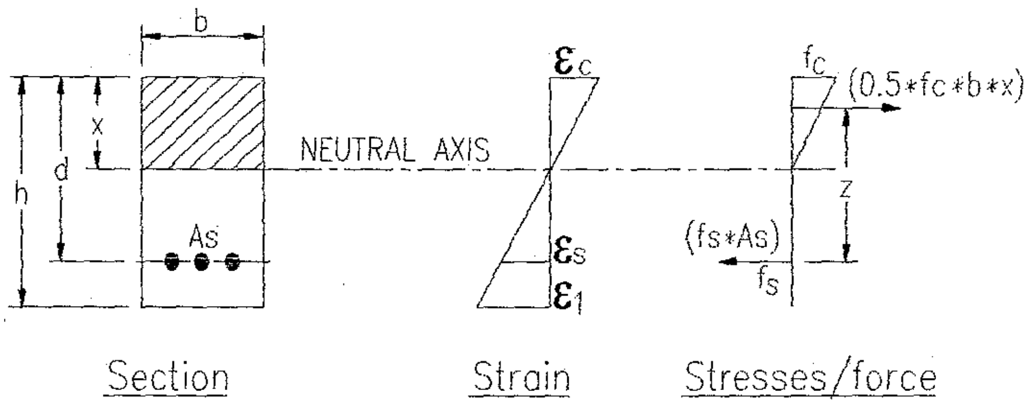
JLATIONS

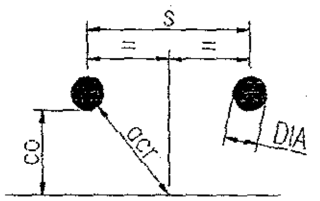
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	114	
Reinforcement stress " **fs** " = Ms/(As*Z) =	273	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	6.44	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001737	
Strain due to stiffening effect of concrete between cracks " $\varepsilon 2$ " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000630	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1-\varepsilon_2$ =	0.001107	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.14** **mm**

WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

'acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	12.2	KNm

TIONS

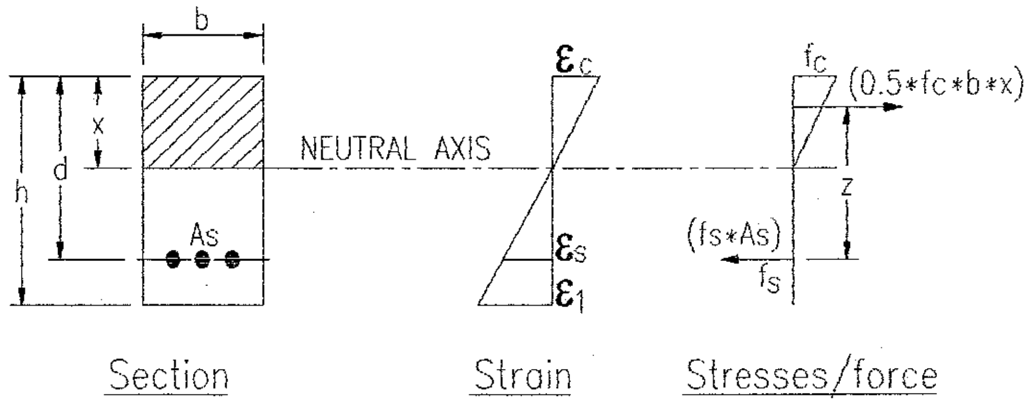
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	114	
Reinforcement stress " **fs** " = Ms/(As*Z) =	273	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	6.44	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001737	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000630	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001107	

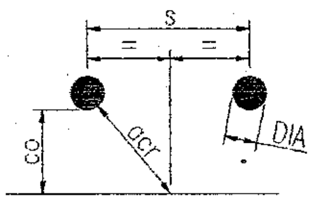
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.14**	**mm**

Spreadsheets to BS 8110etc Advisory Group Slab C-D/14-18 (10mm) Crack Width Calculations to BS8110: 1997/ BS8007:1987 Originated from RCC14.xls on CD © 1999 BCA for RCC	REINFORCED CONCRETE COUNCIL		
	Made by RC	Date 19-Jun-2007	Page 33
	Checked chg	Revision -	Job No R68

‹ WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	314	mm^2
b =	1000	mm
h =	100	mm
d =	75	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	250	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	122.5	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	4.3	KNm

ILATIONS

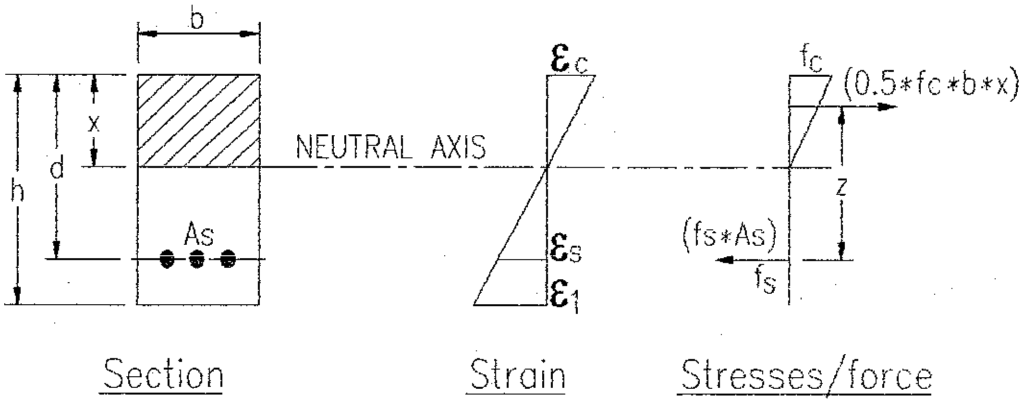
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	23	mm
" **Z** " = d-(x/3) =	67	
Reinforcement stress " **fs** " = Ms/(As*Z) =	205	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	5.71	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001512	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000607	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.000904	

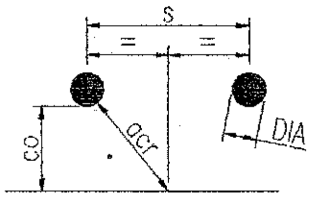
Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

CALCULATED CRACK WIDTH, 'w' =	**0.09**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Slab D-E/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

(WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	5.2	KNm

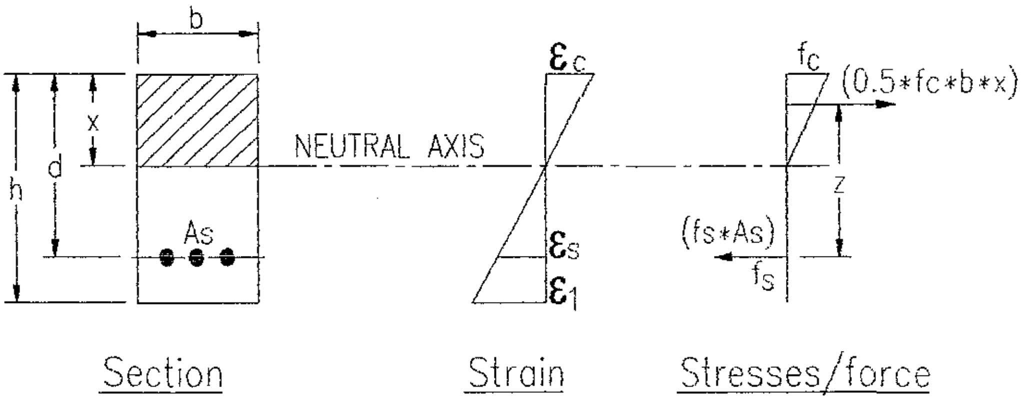
ILATIONS

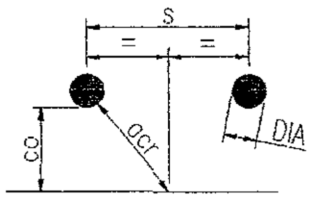
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	90	
Reinforcement stress " **fs** " = Ms/(As*Z) =	148	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	3.97	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001000	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000550	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.000450	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.05**	**mm**

(WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
. . Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.4	KNm

)LATIONS

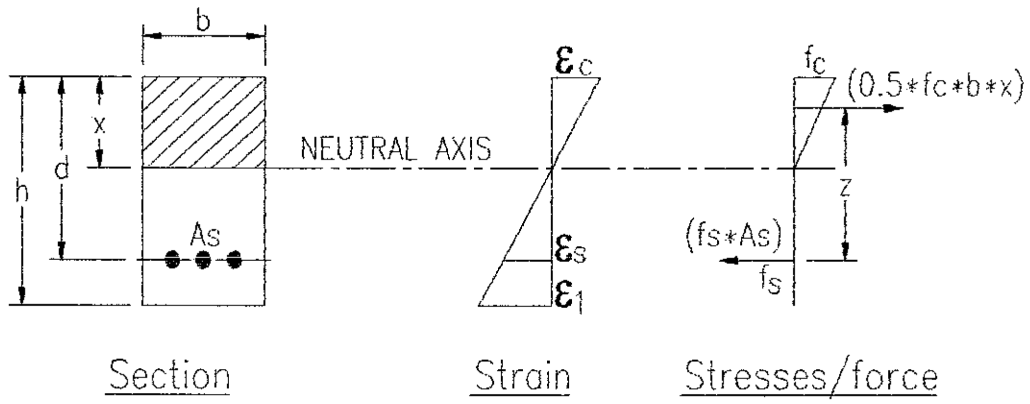
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	25	mm
" **Z** " = d-(x/3) =	92	
Reinforcement stress " **fs** " = Ms/(As*Z) =	432	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	9.19	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002877	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000850	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.002027	

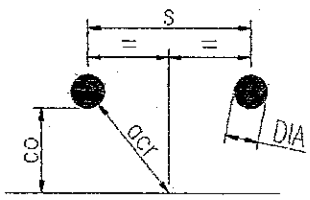
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.25**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
G-J/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

(WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.1	KNm

ILATIONS

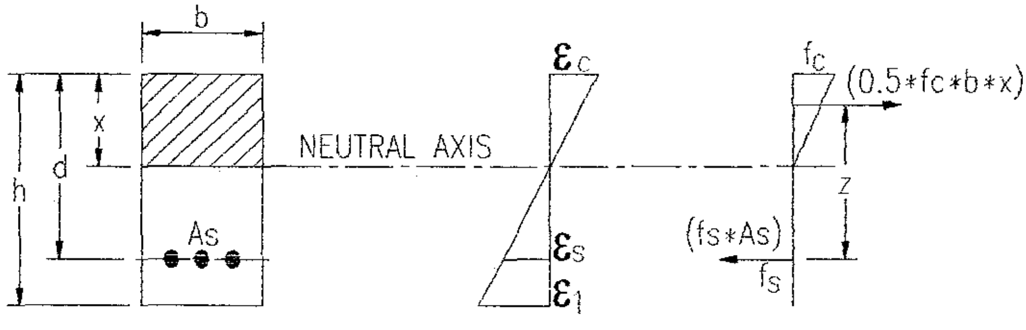
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	25	mm
" **Z** " = d-(x/3) =	92	
Reinforcement stress " **fs** " = Ms/(As*Z) =	420	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.92	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002794	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000850	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001944	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

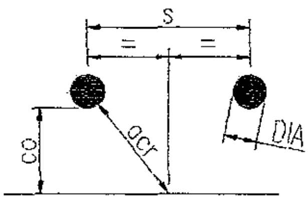
CALCULATED CRACK WIDTH, 'W' =	**0.24**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
J-K/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

(WIDTH CALCULATIONS - FLEXURE



Section   Strain   Stresses/force



fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
' $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

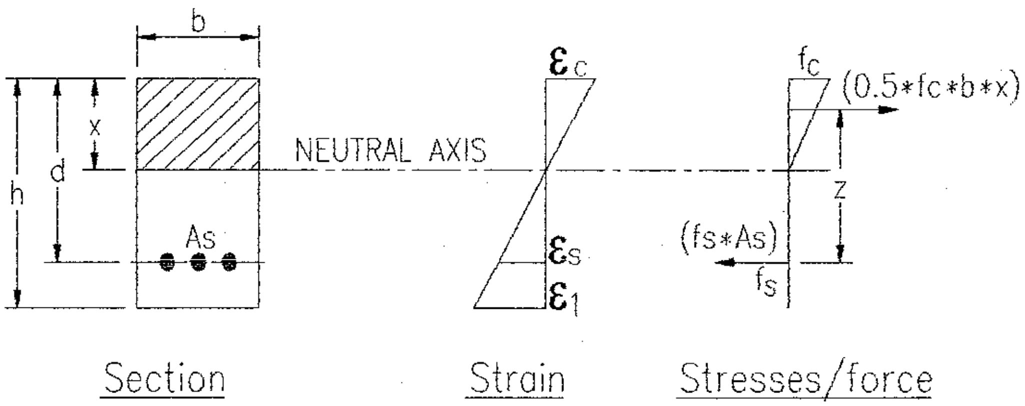
"acr " is distance from the point considered to the surface of the nearest longitudinal bar

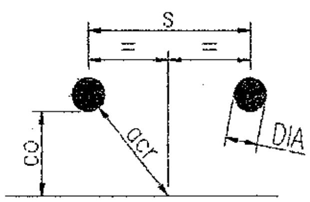
Applied service moment " **Ms** "=	10.1	KNm

LATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	25	mm
" **Z** " = d-(x/3) =	92	
Reinforcement stress " **fs** " = Ms/(As*Z) =	420	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.92	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002794	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000850	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001944	
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$		
CALCULATED CRACK WIDTH, 'W' =	**0.24**	**mm**

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	18.3	KNm

JLATIONS

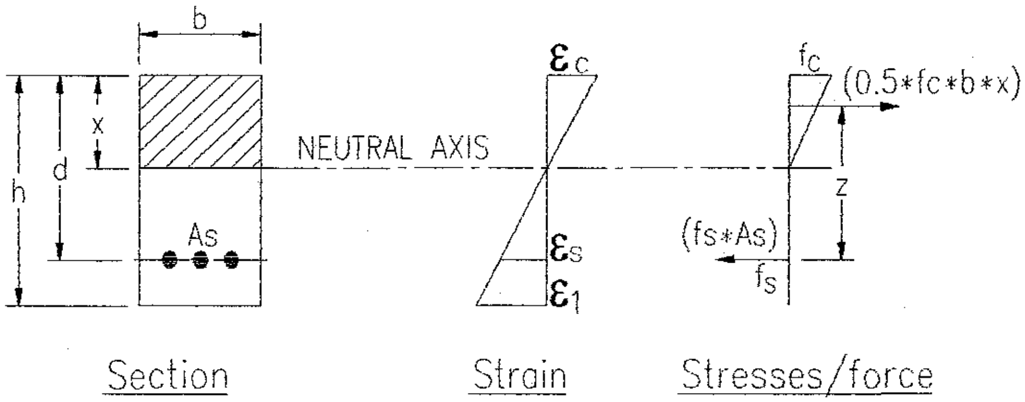
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	114	
Reinforcement stress " **fs** " = Ms/(As*Z) =	409	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	9.66	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002604	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000630	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001974	

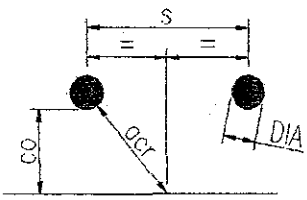
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' =	**0.25**	**mm**

Spreadsheets to BS 8110etc		REINFORCED CONCRETE COUNCIL		
Advisory Group		Made by	Date	Page
M-P/14-18 (10mm)		RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987		Checked	Revision	Job No
Originated from RCC14.xls on CD	© 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

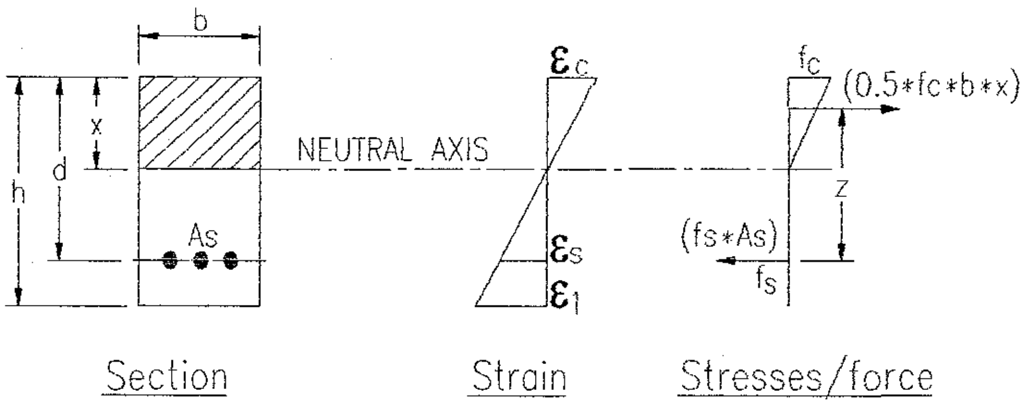
Applied service moment " **Ms** "=	18.3	KNm

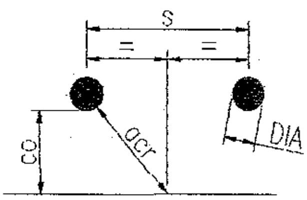
JLATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	114	
Reinforcement stress " **fs** " = Ms/(As*Z) =	409	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	9.66	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002604	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000630	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001974	
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$		
CALCULATED CRACK WIDTH, 'w' =	**0.25**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
P-R/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.1	KNm

ILATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	25	mm
" **Z** " = d-(x/3) =	92	
Reinforcement stress " **fs** " = Ms/(As*Z) =	420	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.92	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002794	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000850	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001944	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.24**	**mm**

Spreadsheets to BS 8110etc

Advisory Group

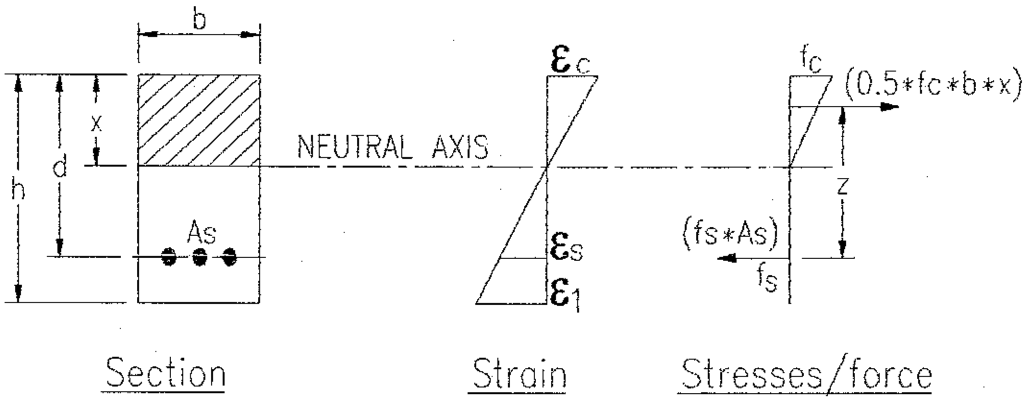
R-T/14-18 (10mm)

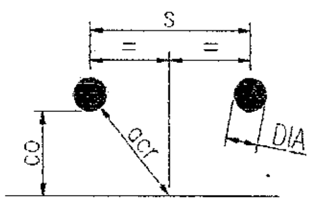
Crack Width Calculations to BS8110: 1997/ BS8007:1987

REINFORCED CONCRETE COUNCIL

Made by	Date	Page
RC	19-Jun-2007	33
Checked	Revision	Job No
chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.1	KNm

JLATIONS

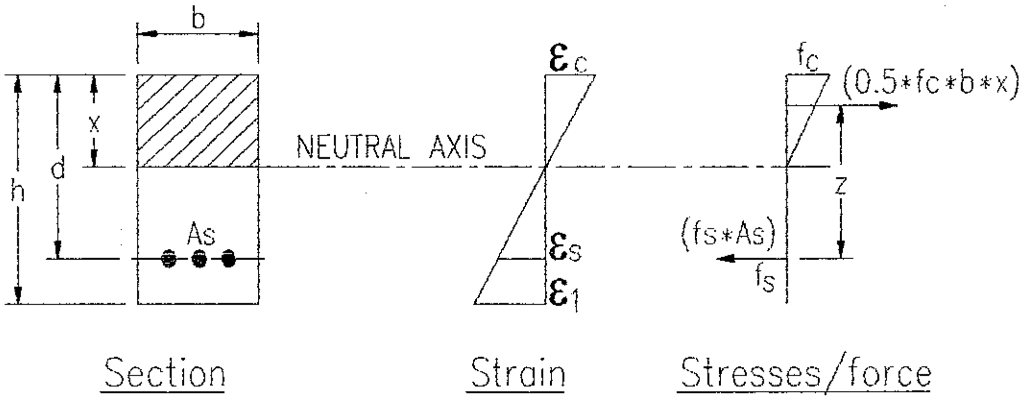
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	25	mm
" **Z** " = d-(x/3) =	92	
Reinforcement stress " **fs** " = Ms/(As*Z) =	420	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.92	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002794	
Strain due to stiffening effect of concrete between cracks " $\varepsilon 2$ " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000850	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001944	

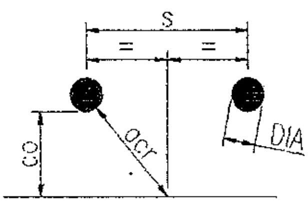
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.24**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group T-V/14-18 (10mm)	Made by RC	Date 19-Jun-2007	Page 33
Crack Width Calculations to BS8110: 1997/ BS8007:1987 Originated from RCC14.xls on CD © 1999 BCA for RCC	Checked chg	Revision -	Job No R68

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	14.9	KNm

JLATIONS

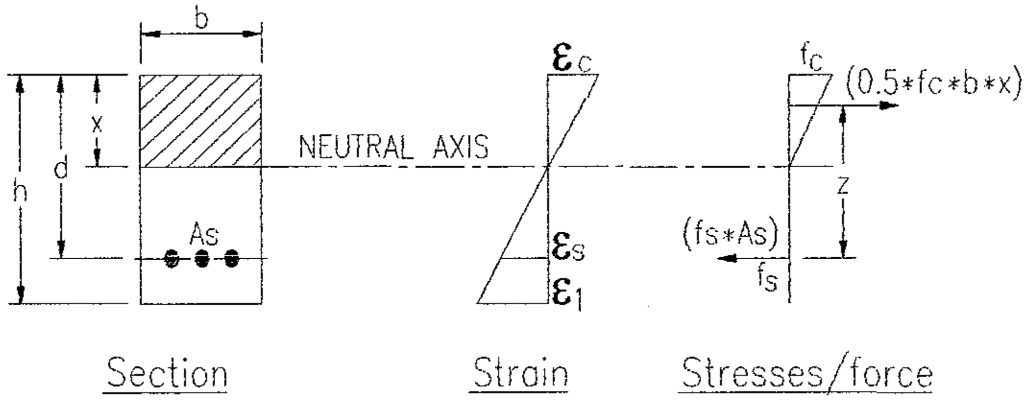
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	90	
Reinforcement stress " **fs** " = Ms/(As*Z) =	419	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	11.25	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.002833	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000550	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.002284	

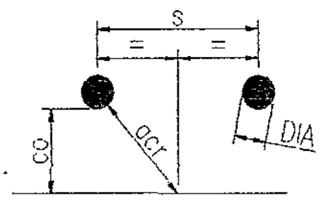
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.26**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group V-W1/14-18 (10mm)	Made by RC	Date 19-Jun-2007	Page 33
Crack Width Calculations to BS8110: 1997/ BS8007:1987 Originated from RCC14.xls on CD © 1999 BCA for RCC	Checked chg	Revision -	Job No R68

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	393	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm.
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	98.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	16.4	KNm

JLATIONS

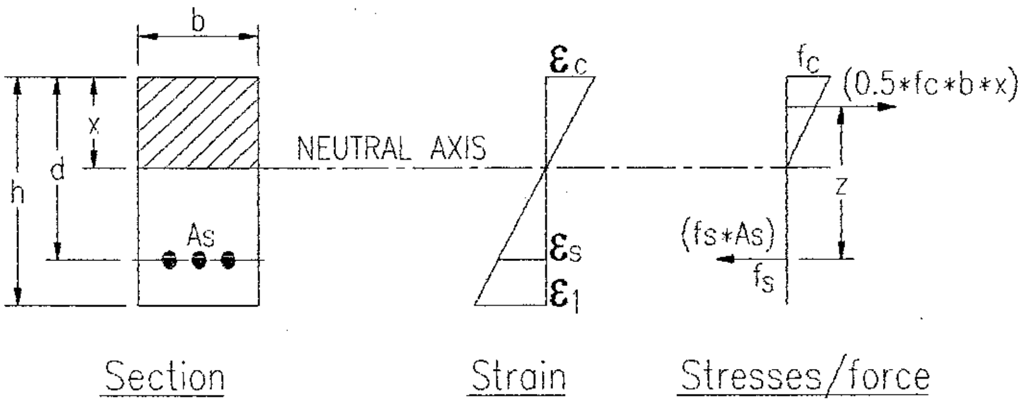
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	90	
Reinforcement stress " **fs** " = Ms/(As*Z) =	461	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	12.39	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.003119	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000550	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.002570	

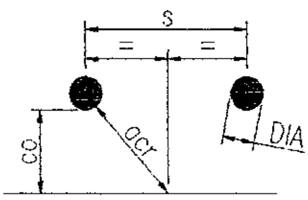
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.29**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
W1-Y/14-18 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

(WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	314	mm^2
b =	1000	mm
h =	125	mm
d =	100	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
.Maxmum bar spacing " **S** " =	250	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	122.5	mm
"acr " is distance from the point considered to the surface of the nearest longitudinal bar		
Applied service moment " **Ms** "=	11.7	KNm

)LATIONS

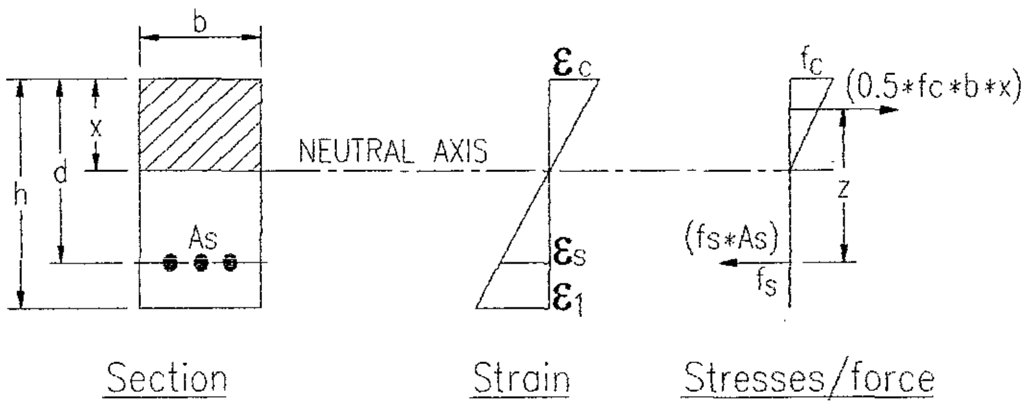
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	27	mm
" **Z** " = d-(x/3) =	91	
Reinforcement stress " **fs** " = Ms/(As*Z) =	408	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	9.61	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002732	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000700	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.002032	

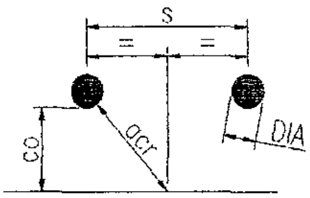
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.24** **mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Y-Ad/14-15 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

(WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	12.1	KNm

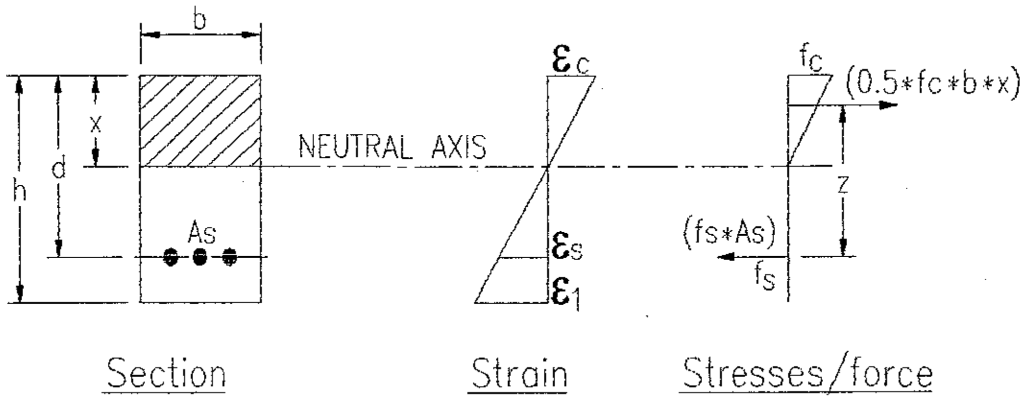
JLATIONS

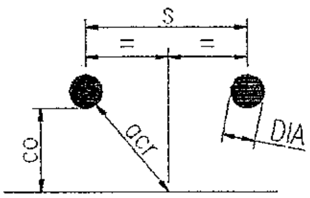
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	398	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.45	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002500	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001524	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.22**	**mm**

‹ WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	8.7	KNm

JLATIONS

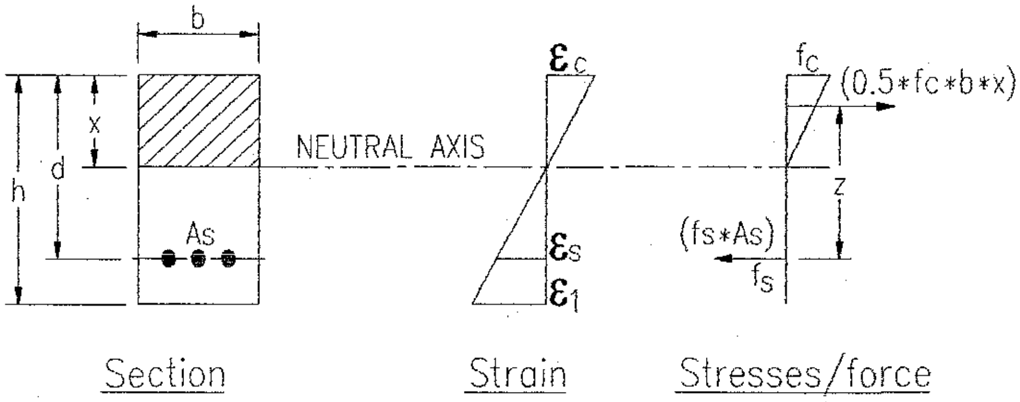
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	287	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	5.37	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001803	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.000827	

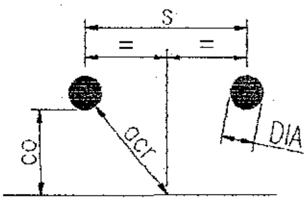
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.12** **mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Y-Z/15-15A (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

‹ WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	100	mm
d =	75	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	1.1	KNm

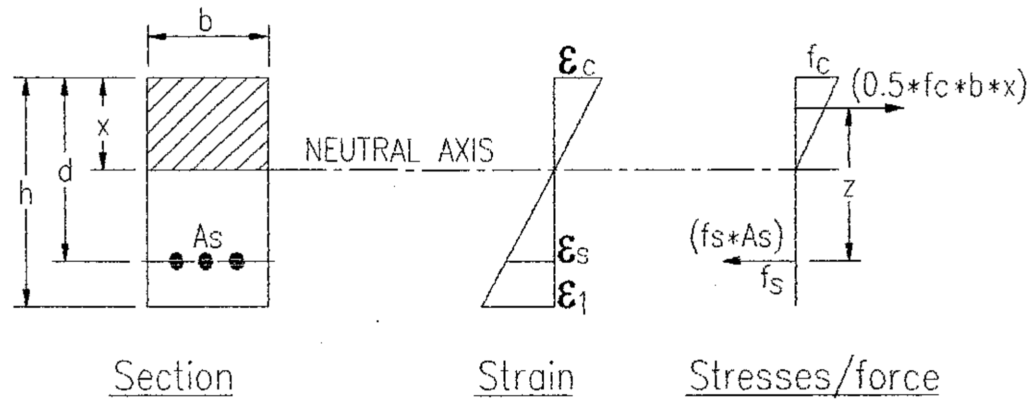
ILATIONS

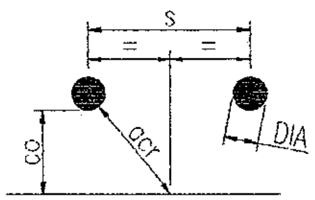
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	21	mm
" **Z** " = d-(x/3) =	68	
Reinforcement stress " **fs** " = Ms/(As*Z) =	59	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	1.49	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000435	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000736	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	-0.000301	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**-0.03**	**mm**

(WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	3.4	KNm

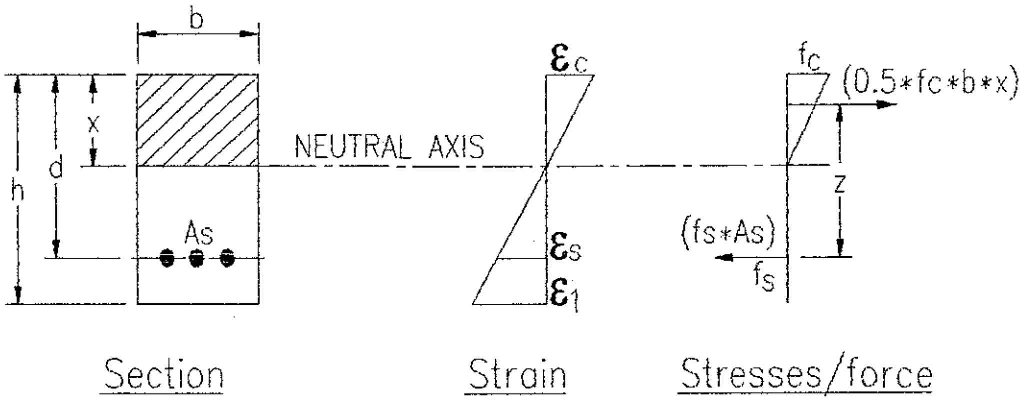
)LATIONS

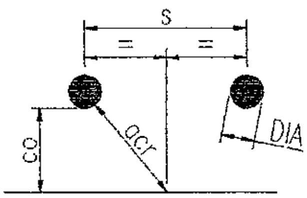
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	112	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	2.10	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.000703	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	-0.000273	

Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

CALCULATED CRACK WIDTH, 'w' =	**-0.04**	**mm**

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	100	mm
d =	75	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	2.5	KNm

JLATIONS

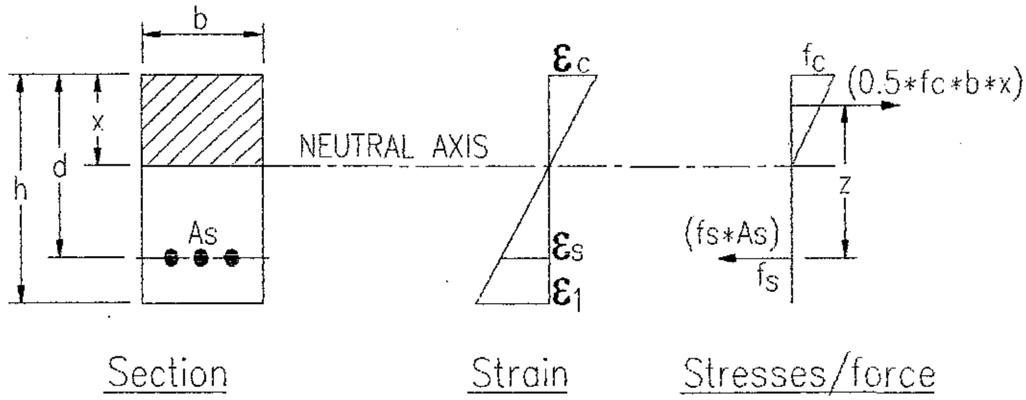
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	21	mm
" **Z** " = d-(x/3) =	68	
Reinforcement stress " **fs** " = Ms/(As*Z) =	139	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	3.49	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.001017	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000736	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.000281	

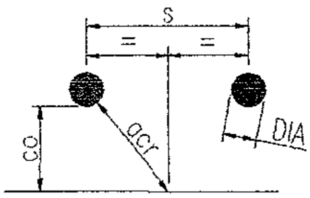
Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

CALCULATED CRACK WIDTH, 'w' =	**0.03**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Z-Ad/15-16 (10mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm²
fy=	460	N/mm²
Area of reinforcement " **As** " =	262	mm²
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	5.6	KNm

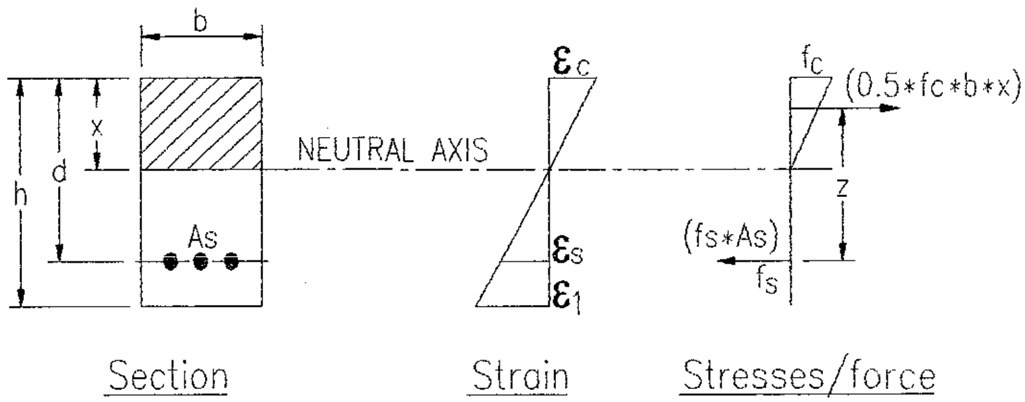
JLATIONS

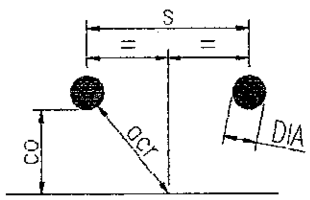
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm²
moduli of elasticity of steel " **Es** " =	200.0	KN/mm²
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	183	N/mm²
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	3.44	N/mm²
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001154	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.000177	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.03** **mm**

‹ WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	262	mm^2
b =	1000	mm
h =	150	mm
d =	125	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	10	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	147.1	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	5.7	KNm

JLATIONS

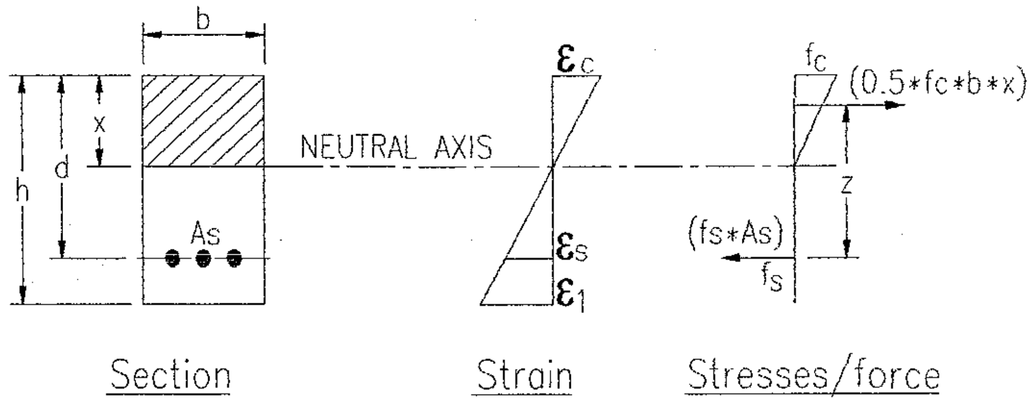
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " **α** " = (Es/Ec) =	15.38	
" **ρ** " = As/bd =	0.002	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	116	
Reinforcement stress " **fs** " = Ms/(As*Z) =	189	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	3.54	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.001189	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000976	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.000213	

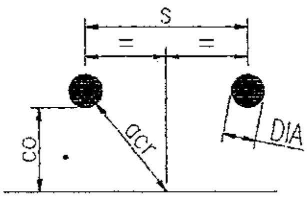
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.03**	**mm**

Appendix 7: Flexural Cracking Calculation for 12mm diameter bar

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	7.8	KNm

JLATIONS

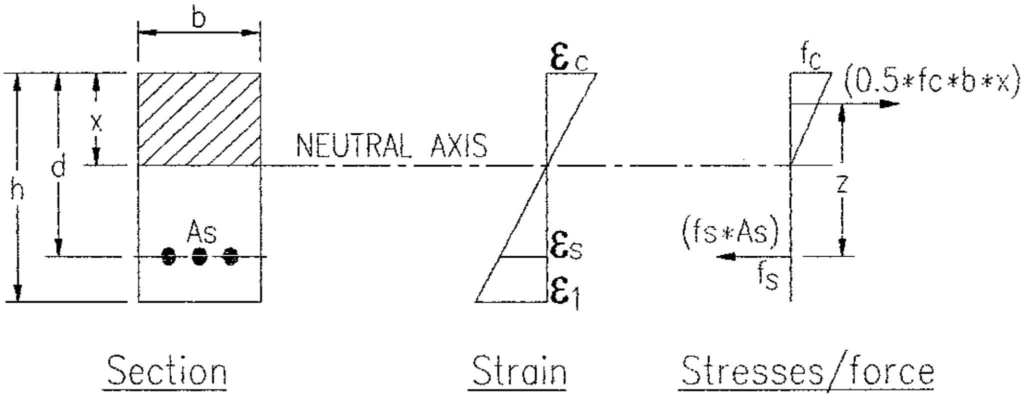
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	182	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	4.22	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001170	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.000503	

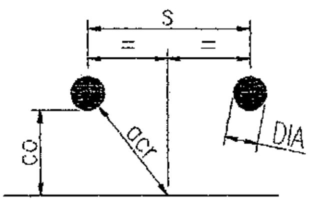
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.07**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Ae1-Af/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

< WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	11.2	KNm

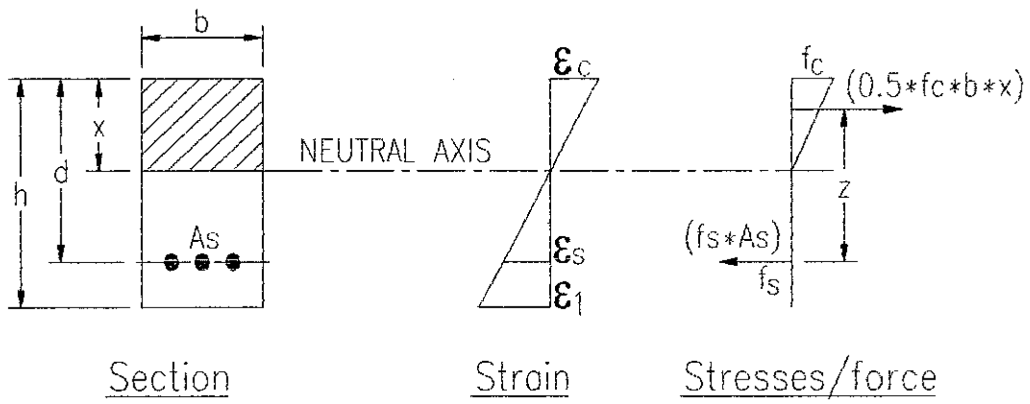
JLATIONS

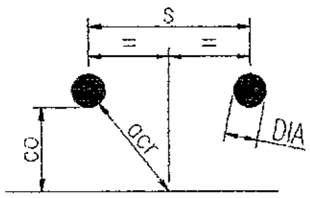
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
"**Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	262	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	6.06	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.001680	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001013	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.14** **mm**

< WIDTH CALCULATIONS - FLEXURE





fcu= 30 N/mm²

fy= 460 N/mm²

Area of reinforcement " **As** " = 377 mm²

b = 1000 mm

h = 150 mm

d = 124 mm

Minimum cover to tension reinforcement " **CO** " = 20 mm

Maxmum bar spacing " **S** " = 300 mm

Bar dia " **DIA** " = 12 mm

" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value = 146.2 mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "= 7.8 KNm

JLATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) = 13.0 KN/mm²

moduli of elasticity of steel " **Es** " = 200.0 KN/mm²

Modular ratio " α " = (Es/Ec) = 15.38

" ρ " = As/bd = 0.003

depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ = 33 mm

" **Z** " = d-(x/3) = 113

Reinforcement stress " **fs** " = Ms/(As*Z) = 182 N/mm²

Concrete stress " **fc** " = (fs*As)/(0.5*b*x) = 4.22 N/mm²

Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) = 0.001170

Strain due to stiffening effect of concrete between cracks " ε**2** " =

$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm Used

$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm n/a

ε_2 = 0.000667

Average strain for calculation of crack width " ε_m "= ε_1-ε_2 = 0.000503

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' = **0.07** **mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
C-D/14-18 (12mm)	RC	19-Jun-2007	33
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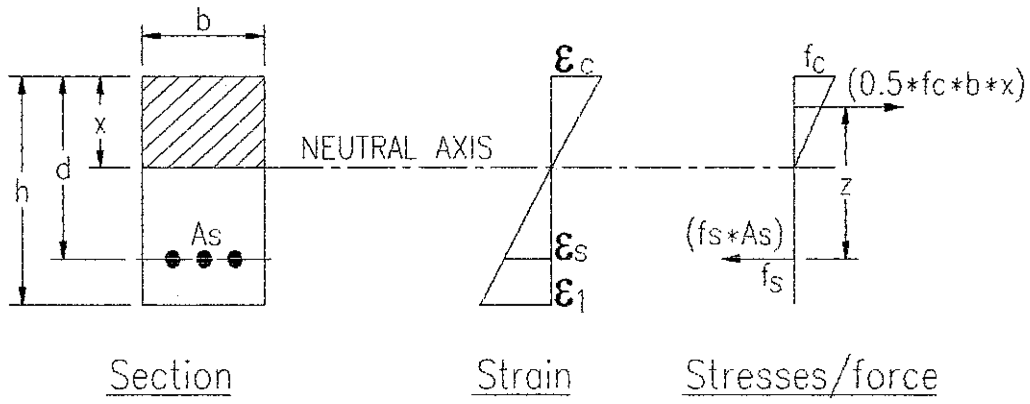
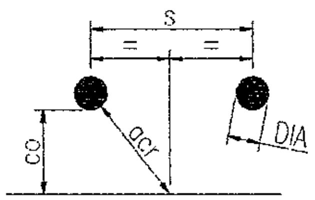
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	503	mm^2
b =	1000	mm
h =	100	mm
d =	74	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	225	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	109.5	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	4.0	KNm

JLATIONS

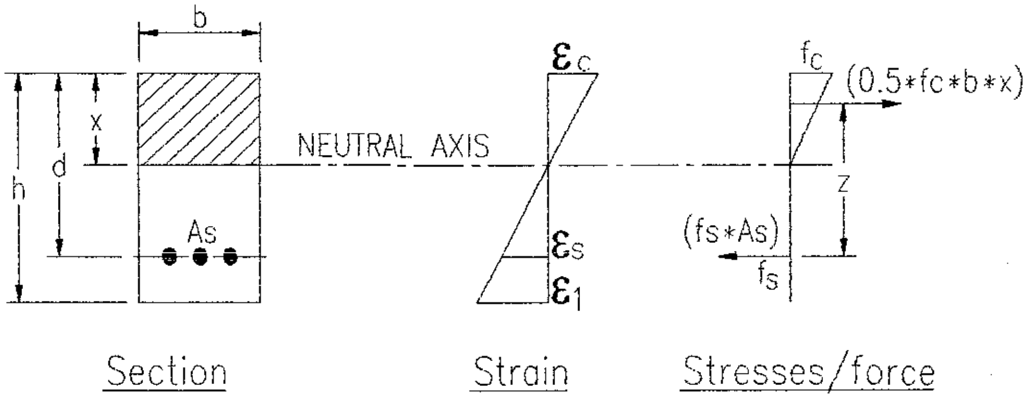
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.007	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	27	mm
" **Z** " = d-(x/3) =	65	
Reinforcement stress " **fs** " = Ms/(As*Z) =	123	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	4.60	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000957	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000376	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.000581	

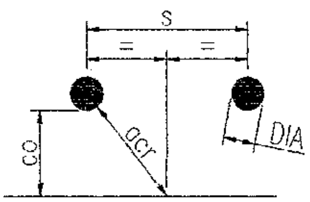
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' =	**0.06**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
D-E/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

< WIDTH CALCULATIONS - FLEXURE





fcu= 30 N/mm²

fy= 460 N/mm²

Area of reinforcement " **As** " = 377 mm²

b = 1000 mm

h = 125 mm

d = 99 mm

Minimum cover to tension reinforcement " **CO** " = 20 mm

Maxmum bar spacing " **S** " = 300 mm

Bar dia " **DIA** " = 12 mm

" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value = 146.2 mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "= 5.0 KNm

JLATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) = 13.0 KN/mm²

moduli of elasticity of steel " **Es** " = 200.0 KN/mm²

Modular ratio " α " = (Es/Ec) = 15.38

" ρ " = As/bd = 0.004

depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ = 29 mm

" **Z** " = d-(x/3) = 89

Reinforcement stress " **fs** " = Ms/(As*Z) = 148 N/mm²

Concrete stress " **fc** " = (fs*As)/(0.5*b*x) = 3.91 N/mm²

Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) = 0.001015

Strain due to stiffening effect of concrete between cracks " ε**2** " =

$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm Used

$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm n/a

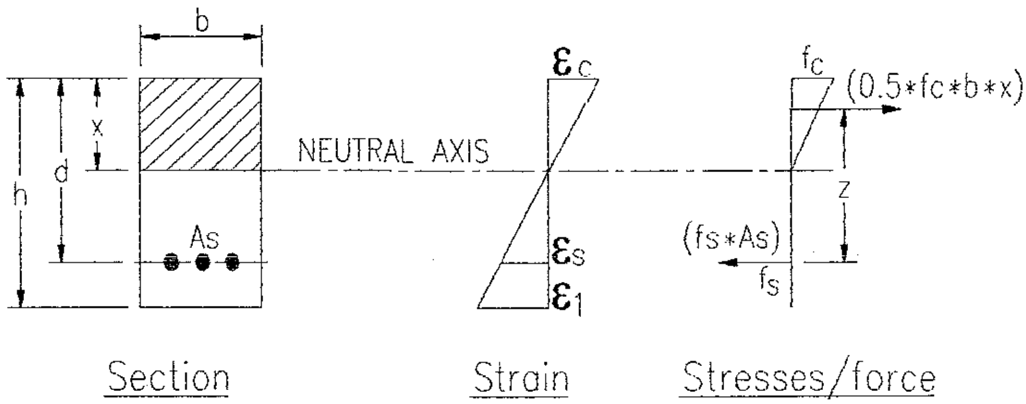
ε_2 = 0.000584

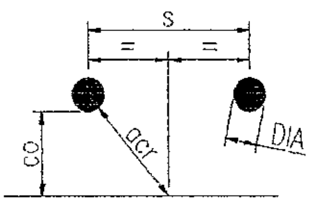
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 = 0.000431

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.05** **mm**

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.9	KNm

JLATIONS

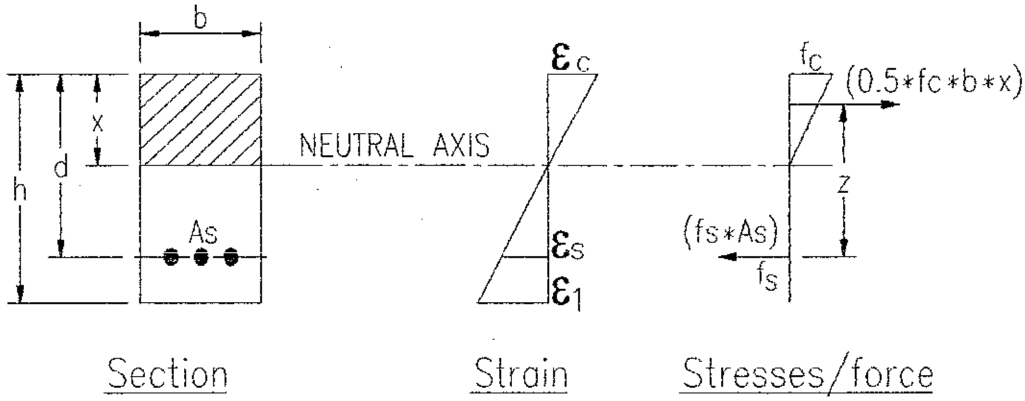
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	294	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.76	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002013	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001430	

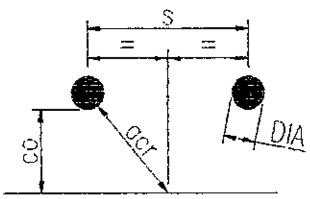
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.17**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
G-J/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.6	KNm

ULATIONS

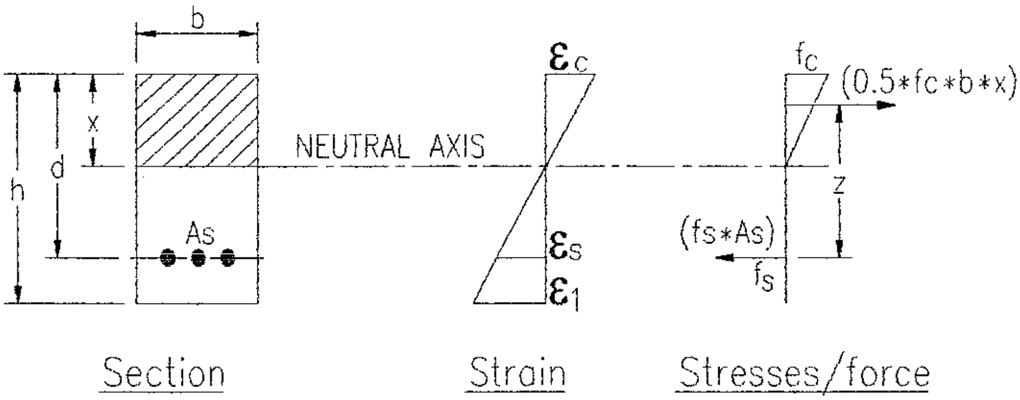
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	285	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.53	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001954	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001371	

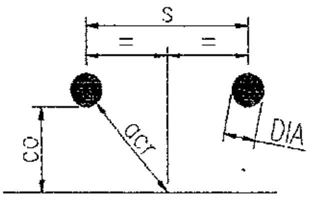
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.17** **mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
J-K/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

‹ WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.6	KNm

JLATIONS

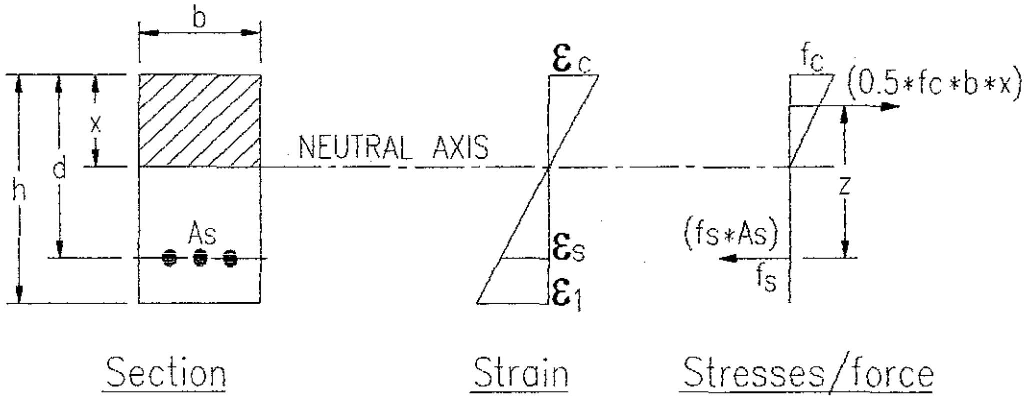
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	285	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.53	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001954	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001371	

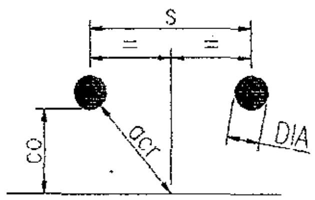
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.17**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
K-M/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	566	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	97.3	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

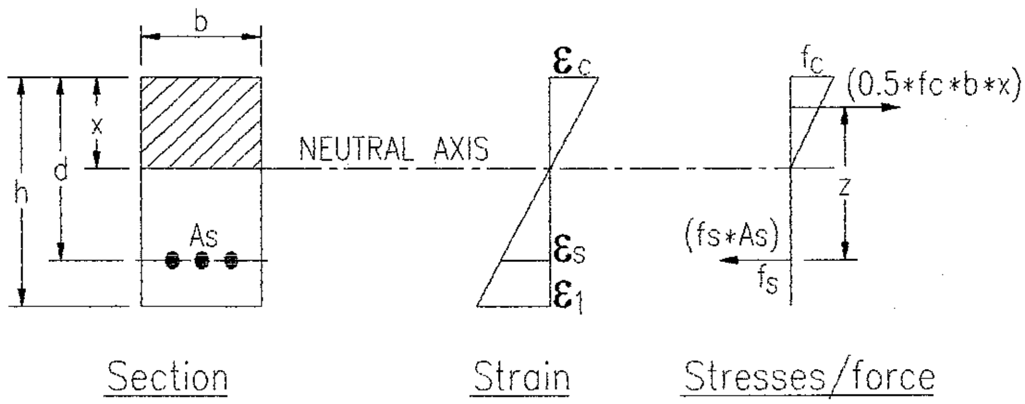
Applied service moment " **Ms** "=	17.5	KNm

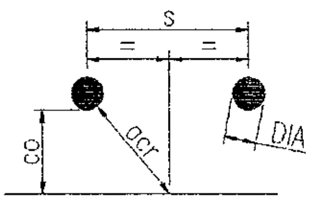
ULATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.005	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	39	mm
" **Z** " = d-(x/3) =	111	
Reinforcement stress " **fs** " = Ms/(As*Z) =	279	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.18	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001818	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000428	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001390	
Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))		
CALCULATED CRACK WIDTH, 'w' =	**0.17**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
M-P/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	566	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	97.3	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	17.5	KNm

JLATIONS

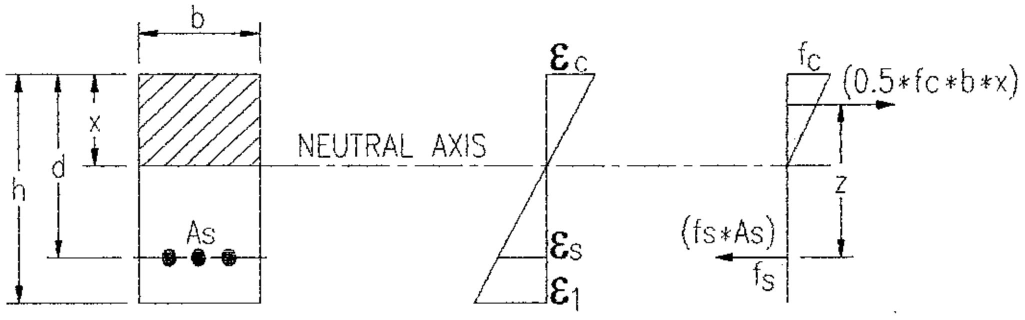
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.005	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	39	mm
" **Z** " = d-(x/3) =	111	
Reinforcement stress " **fs** " = Ms/(As*Z) =	279	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.18	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001818	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000428	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001390	

Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

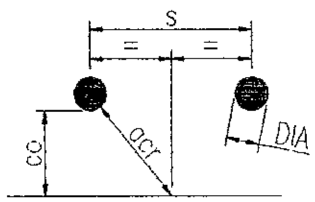
CALCULATED CRACK WIDTH, 'w' =	**0.17**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
P-R/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

< WIDTH CALCULATIONS - FLEXURE



Section   Strain   Stresses/force



fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.6	KNm

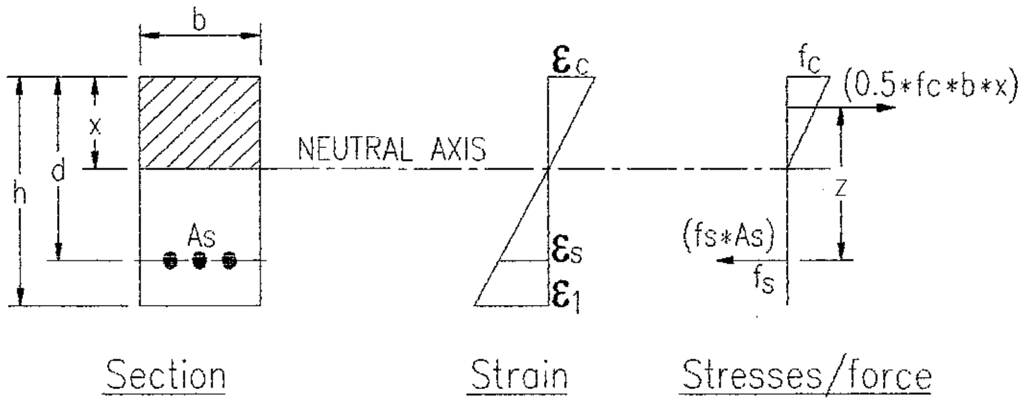
JLATIONS

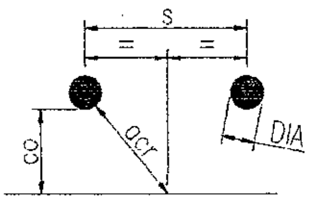
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	285	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.53	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001954	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001371	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' = **0.17** **mm**

< WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.6	KNm

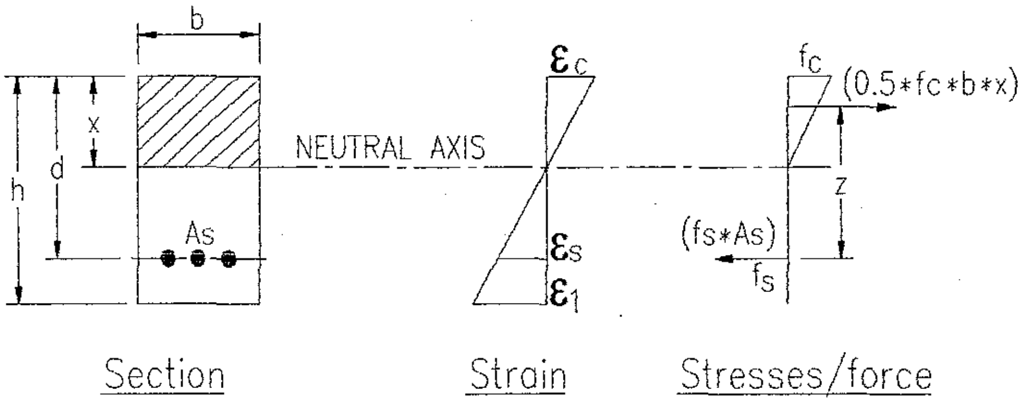
JLATIONS

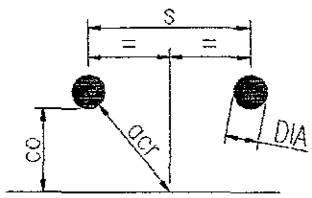
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	285	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.53	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.001954	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001371	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **0.17** **mm**

‹ WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	9.9	KNm

ULATIONS

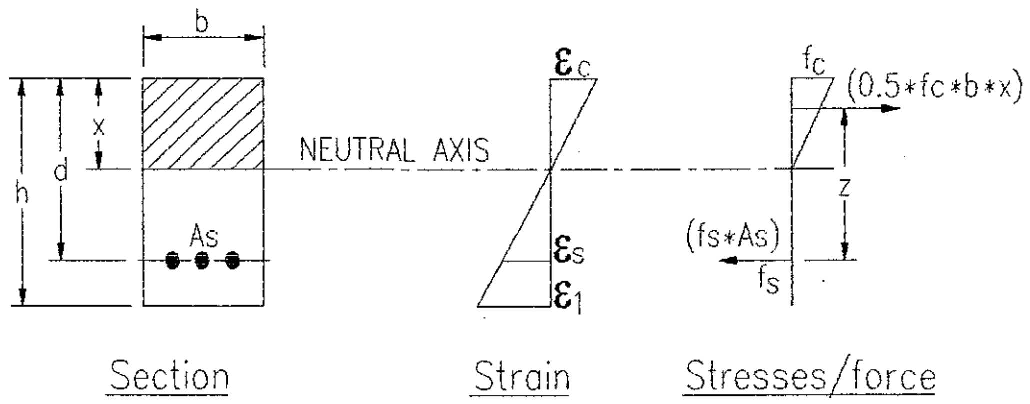
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	294	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	7.76	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002013	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001430	

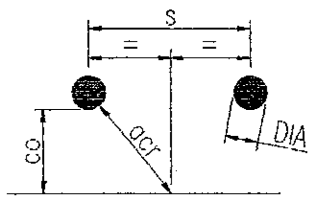
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**0.17**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
V-W1/14-18 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.3	KNm

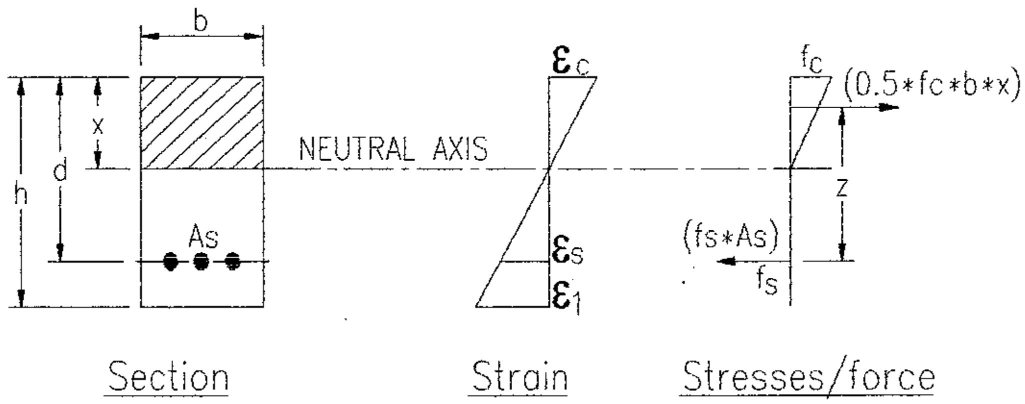
ULATIONS

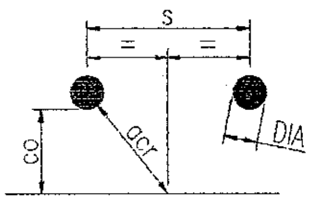
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	305	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.04	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002086	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	0.001503	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' = **0.18** **mm**

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	125	mm
d =	99	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	10.4	KNm

JLATIONS

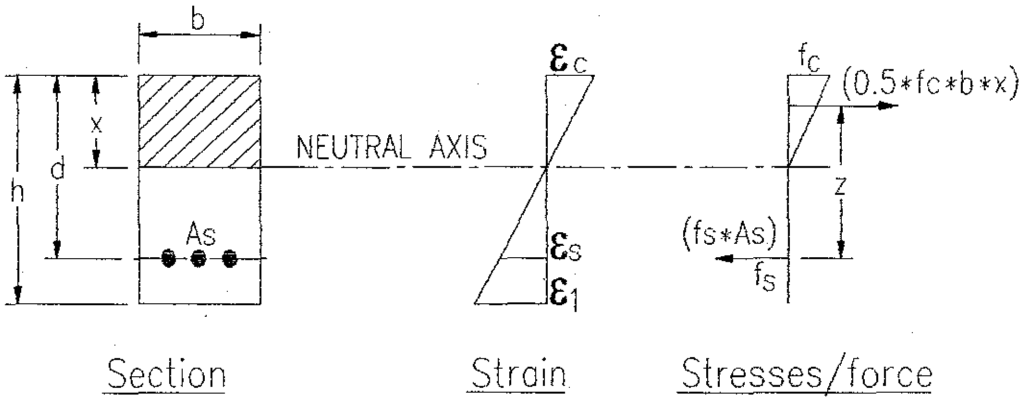
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.004	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	29	mm
" **Z** " = d-(x/3) =	89	
Reinforcement stress " **fs** " = Ms/(As*Z) =	308	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	8.12	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.002107	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000584	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	0.001523	

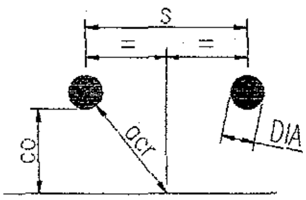
Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

CALCULATED CRACK WIDTH, 'w' =	**0.18**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Y-Ad/14-15 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	2.2	KNm

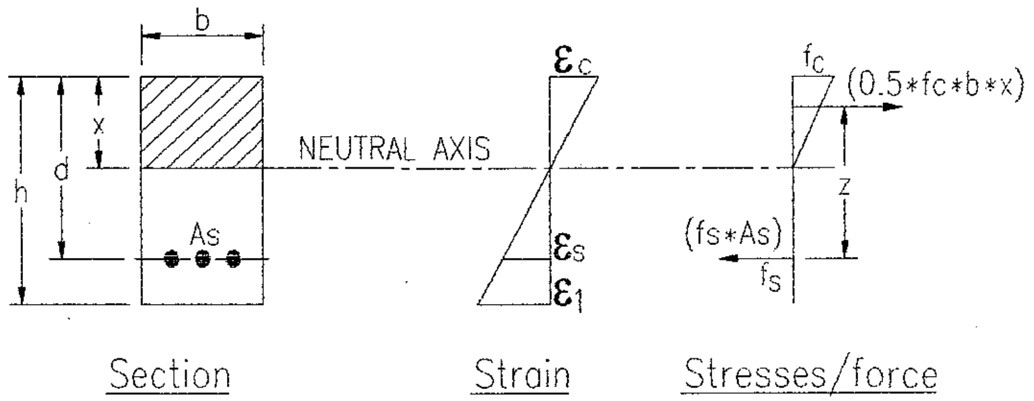
ILATIONS

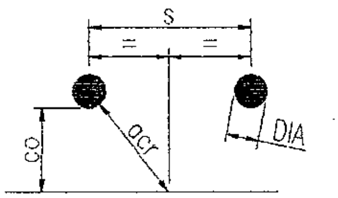
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	52	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	1.20	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.000333	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	-0.000334	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'W' =	**-0.05**	**mm**

K WIDTH CALCULATIONS - FLEXURE





fcu= 30 N/mm^2
fy= 460 N/mm^2
Area of reinforcement " **As** " = 377 mm^2
b = 1000 mm
h = 150 mm
d = 124 mm
Minimum cover to tension reinforcement " **CO** " = 20 mm
Maxmum bar spacing " **S** " = 300 mm
Bar dia " **DIA** " = 12 mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value = 146.2 mm
"acr " is distance from the point considered to the surface of the nearest longitudinal bar
Applied service moment " **Ms** "= 2.2 KNm

ULATIONS

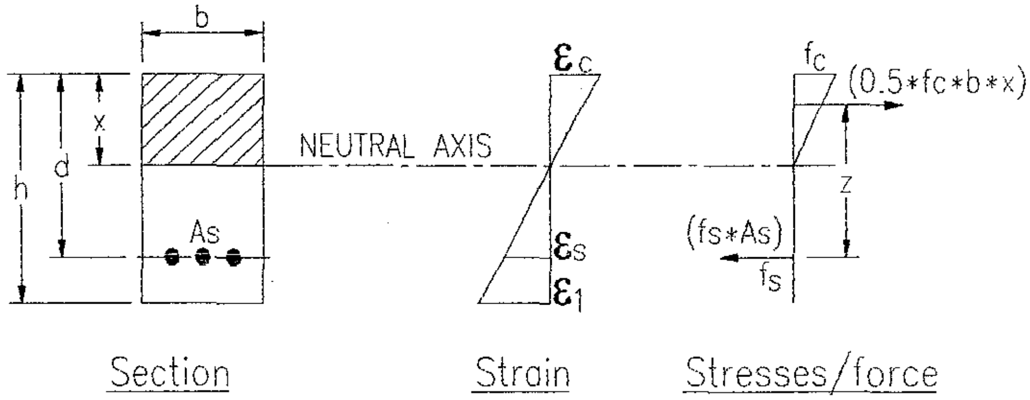
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) = 13.0 KN/mm^2
moduli of elasticity of steel " **Es** " = 200.0 KN/mm^2
Modular ratio " α " = (Es/Ec) = 15.38
" ρ " = As/bd = 0.003
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ = 33 mm

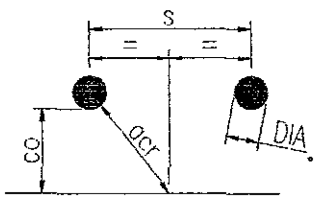
" **Z** " = d-(x/3) = 113
Reinforcement stress " **fs** " = Ms/(As*Z) = 52 N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) = 1.20 N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) = 0.000333
Strain due to stiffening effect of concrete between cracks " **ε2** " =
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm Used
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm n/a
ε_2 = 0.000667
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ = -0.000334

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **-0.05** **mm**

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	566	mm^2
b =	1000	mm
h =	100	mm
d =	74	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	97.3	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	0.5	KNm

ULATIONS

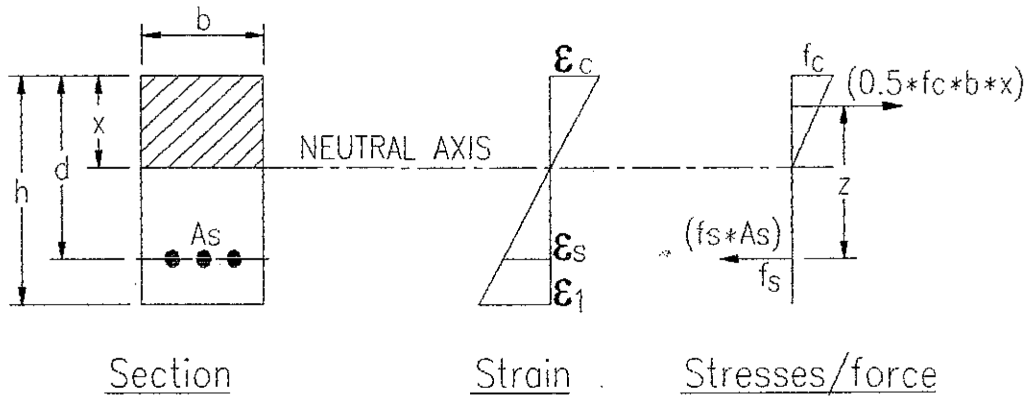
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.008	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	65	
Reinforcement stress " **fs** " = Ms/(As*Z) =	13	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	0.54	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000105	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000331	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	-0.000226	

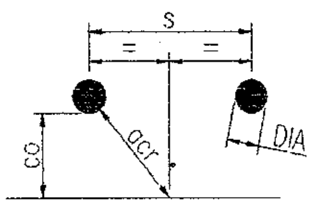
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' =	**-0.02**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Y-Z/15A-16A (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

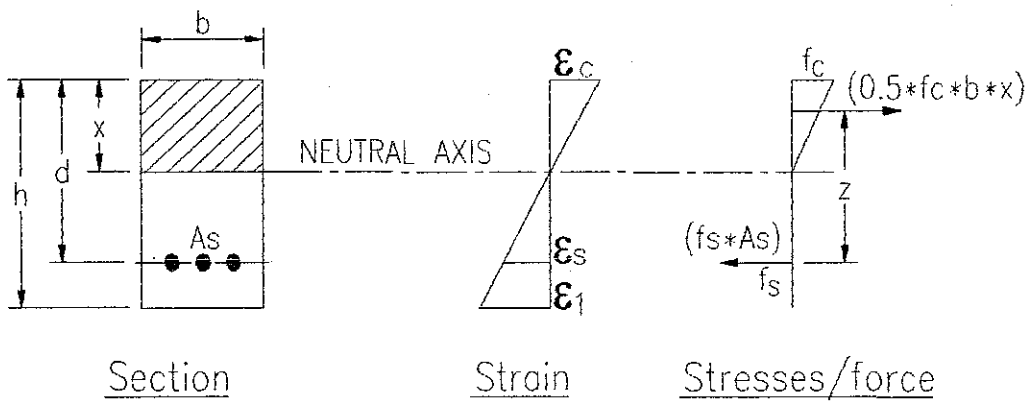
Applied service moment " **Ms** "=	2.2	KNm

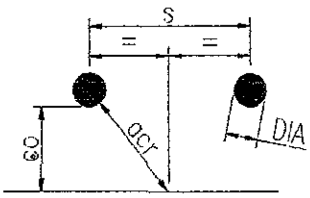
ULATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	52	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	1.20	N/mm^2
Strain at soffit of concrete beam/slab " ε1 " = (fs/Es)*(h-x)/(d-x) =	0.000333	
Strain due to stiffening effect of concrete between cracks " **ε2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1-\varepsilon_2$ =	-0.000334	
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$		
CALCULATED CRACK WIDTH, 'w' =	**-0.05**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Y-Z/16A-17 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	566	mm^2
b =	1000	mm
h =	100	mm
d =	74	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	200	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	97.3	mm

"acr " is distance from the point considered to the surface of the nearest longitudinal bar

Applied service moment " **Ms** "=	0.5	KNm

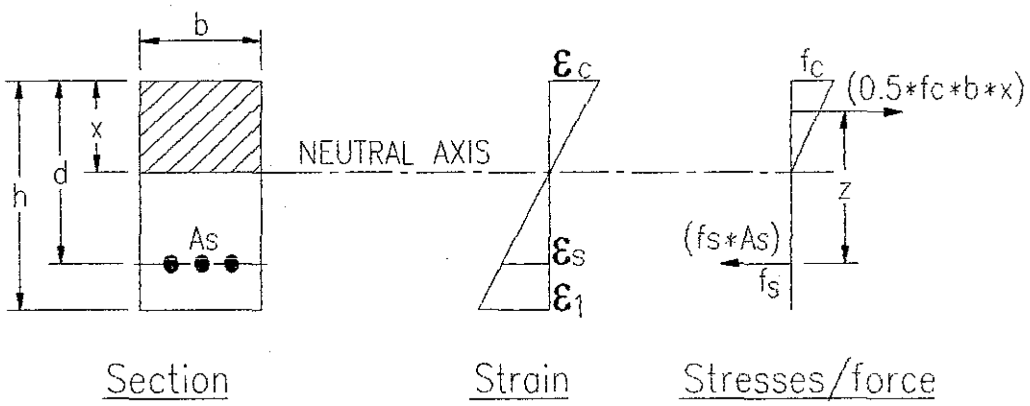
JLATIONS

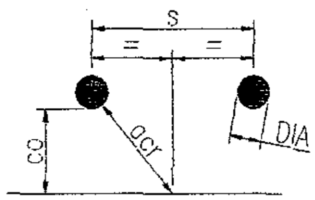
moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.008	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	28	mm
" **Z** " = d-(x/3) =	65	
Reinforcement stress " **fs** " = Ms/(As*Z) =	13	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	0.54	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000105	
Strain due to stiffening effect of concrete between cracks " $\boldsymbol{\varepsilon 2}$ " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000331	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	-0.000226	

Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$

CALCULATED CRACK WIDTH, 'w' = **-0.02** **mm**

K WIDTH CALCULATIONS - FLEXURE





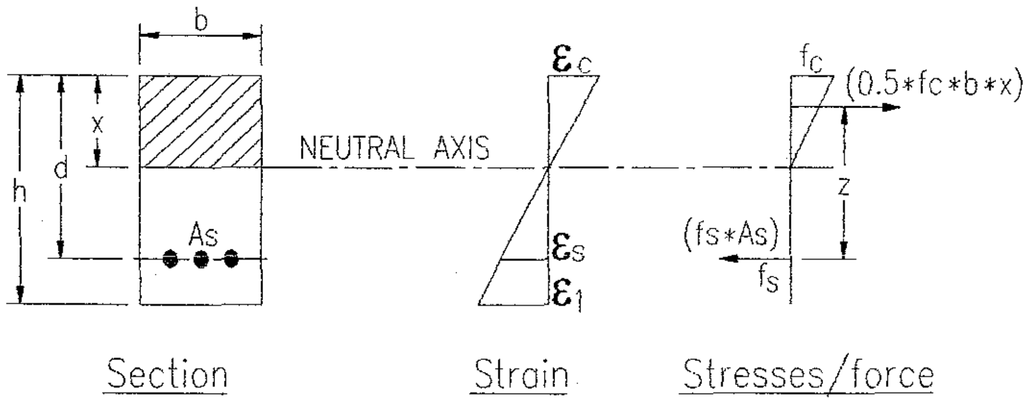
fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" a_{cr} " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm
"acr " is distance from the point considered to the surface of the nearest longitudinal bar		
Applied service moment " **Ms** "=	2.2	KNm

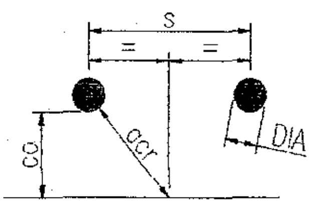
ULATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	52	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	1.20	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000333	
Strain due to stiffening effect of concrete between cracks " ε**2** " =		
$\varepsilon_2 = b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.2 mm	Used	
$\varepsilon_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x))$ for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= $\varepsilon_1 - \varepsilon_2$ =	-0.000334	
Calculated crack width, " w " = $3.a_{cr}.\varepsilon m/(1+2.(a_{cr}-c)/(h-x))$		
CALCULATED CRACK WIDTH, 'w' =	**-0.05**	**mm**

Spreadsheets to BS 8110etc	REINFORCED CONCRETE COUNCIL		
Advisory Group	Made by	Date	Page
Z-Ad/16-17 (12mm)	RC	19-Jun-2007	33
Crack Width Calculations to BS8110: 1997/ BS8007:1987	Checked	Revision	Job No
Originated from RCC14.xls on CD © 1999 BCA for RCC	chg	-	R68

K WIDTH CALCULATIONS - FLEXURE -





fcu=	30	N/mm^2
fy=	460	N/mm^2
Area of reinforcement " **As** " =	377	mm^2
b =	1000	mm
h =	150	mm
d =	124	mm
Minimum cover to tension reinforcement " **CO** " =	20	mm
Maxmum bar spacing " **S** " =	300	mm
Bar dia " **DIA** " =	12	mm
" $\mathbf{a_{cr}}$ " =(((S/2)^2+(CO+DIA/2)^2)^(1/2)-DIA/2) as default or enter other value =	146.2	mm
"acr " is distance from the point considered to the surface of the nearest longitudinal bar		
Applied service moment " **Ms** "=	2.2	KNm

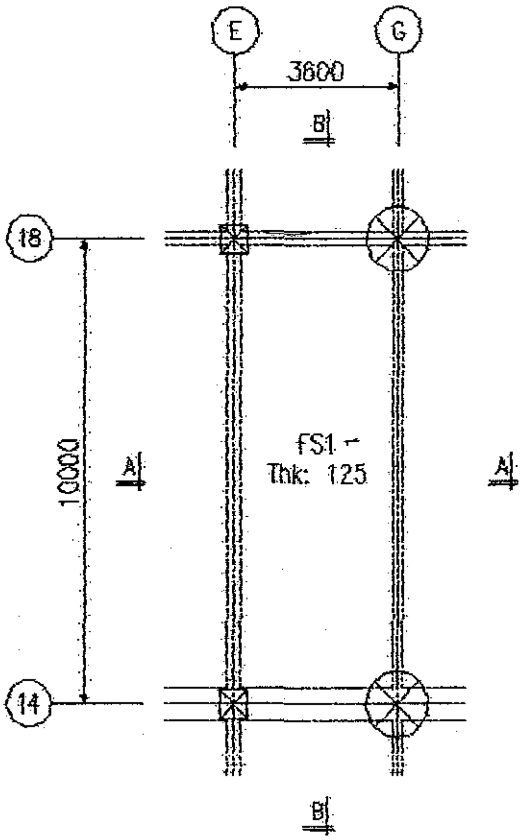
JLATIONS

moduli of elasticity of concrete " **Ec**" = (1/2)*(20+0.2*fcu) =	13.0	KN/mm^2
moduli of elasticity of steel " **Es** " =	200.0	KN/mm^2
Modular ratio " α " = (Es/Ec) =	15.38	
" ρ " = As/bd =	0.003	
depth to neutral axis, "**x**" = $(-\alpha.\rho + ((\alpha.\rho)^2 + 2.\alpha.\rho)^{0.5}.d$ =	33	mm
" **Z** " = d-(x/3) =	113	
Reinforcement stress " **fs** " = Ms/(As*Z) =	52	N/mm^2
Concrete stress " **fc** " = (fs*As)/(0.5*b*x) =	1.20	N/mm^2
Strain at soffit of concrete beam/slab " $\varepsilon 1$ " = (fs/Es)*(h-x)/(d-x) =	0.000333	
Strain due to stiffening effect of concrete between cracks " $\varepsilon\mathbf{2}$ " =		
ε_2 = b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.2 mm	Used	
ε_2 = 1.5.b.(h-x)^2/(3.Es.As.(d-x)) for crack widths of 0.1 mm	n/a	
ε_2 =	0.000667	
Average strain for calculation of crack width " ε_m "= ε_1-ε_2 =	-0.000334	

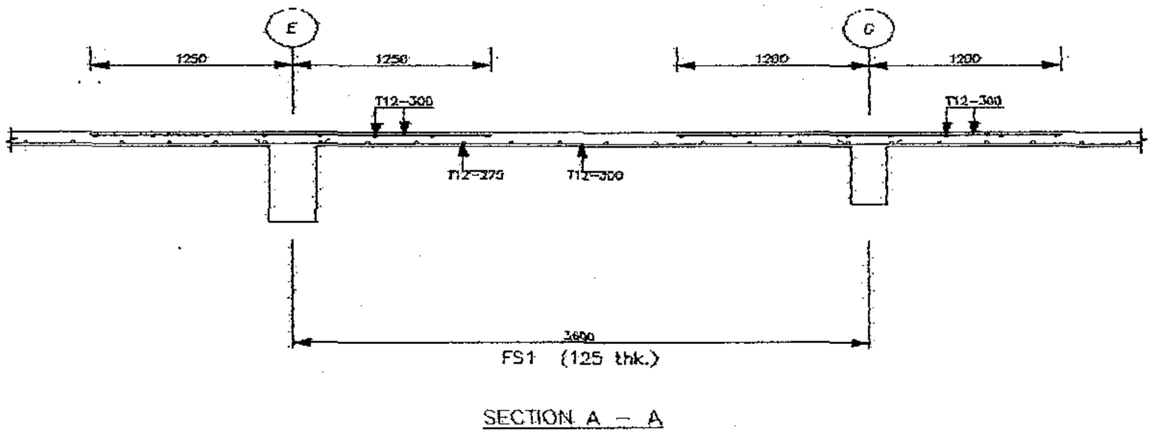
Calculated crack width, " w " = 3.a_{cr}.εm/(1+2.(a_{cr}-c)/(h-x))

CALCULATED CRACK WIDTH, 'w' = **-0.05** **mm**

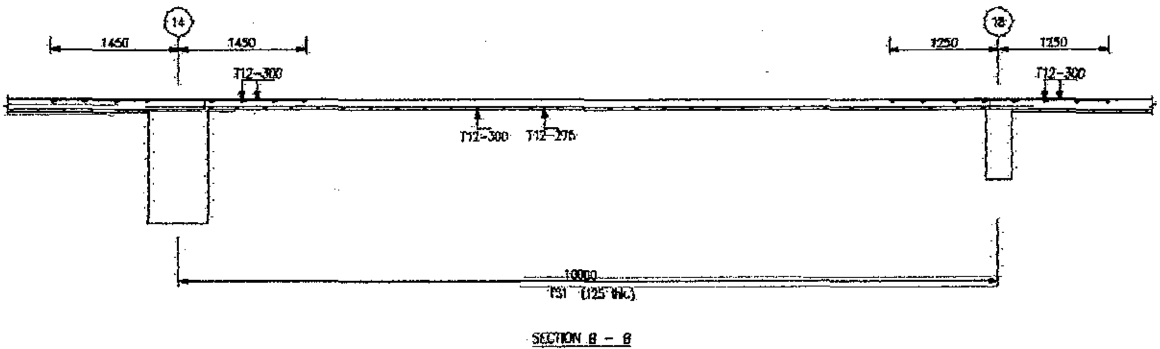
Detail drawing for Slab E-G / 14-18



Slab layout for Slab E-G/14-18

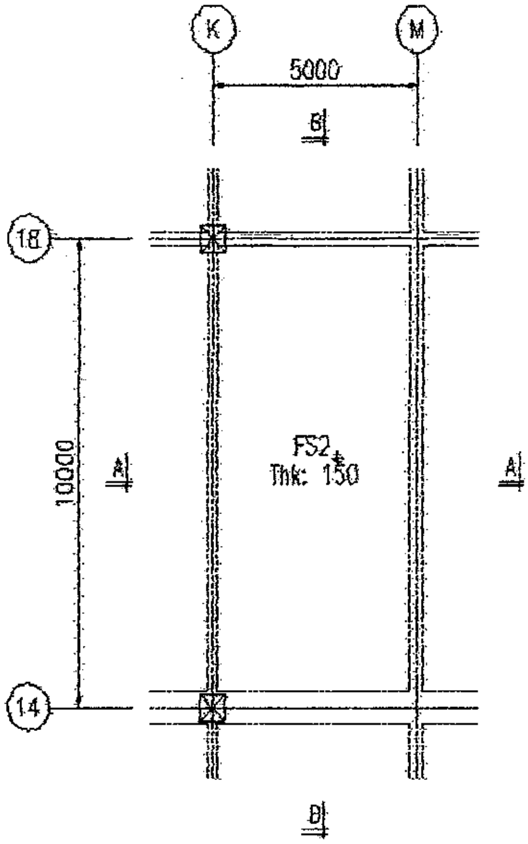


Cross-section of the Slab at A-A for Slab E-G/14-18

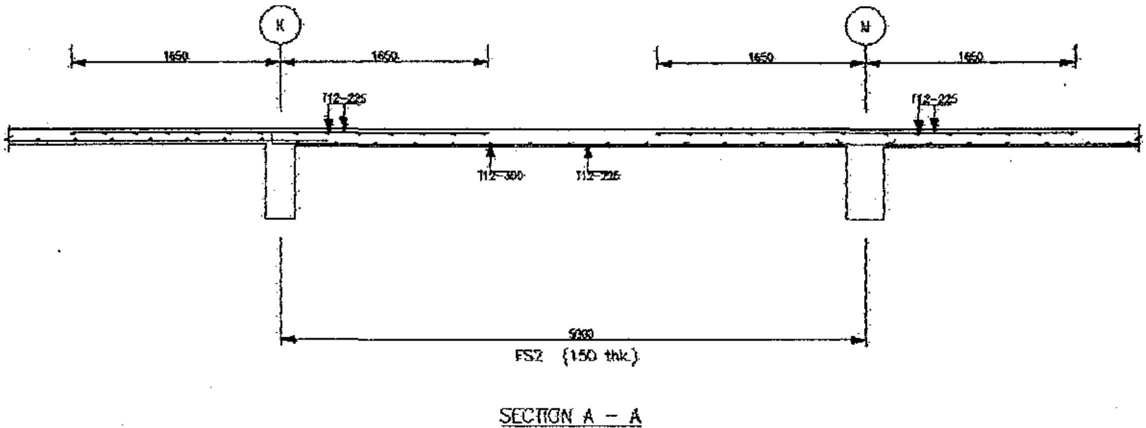


Cross-section of the Slab at B-B for Slab E-G/14-18

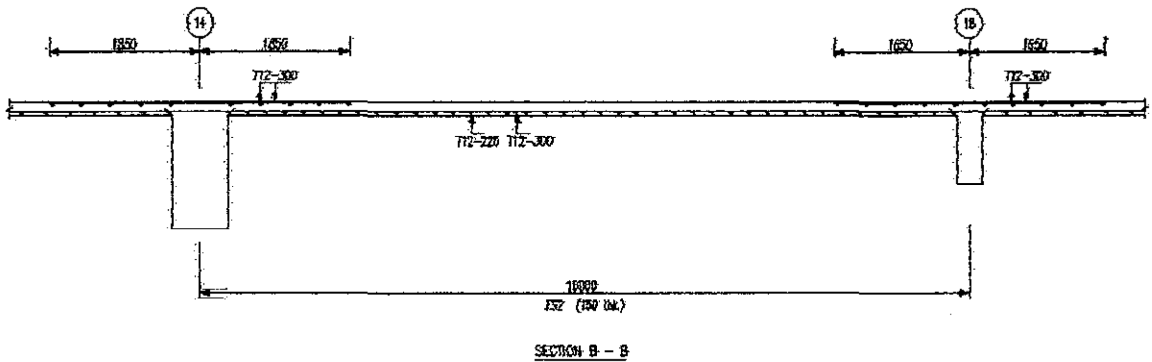
Detail drawing for Slab K-M / 14-18



Slab layout for Slab K-M/14-18

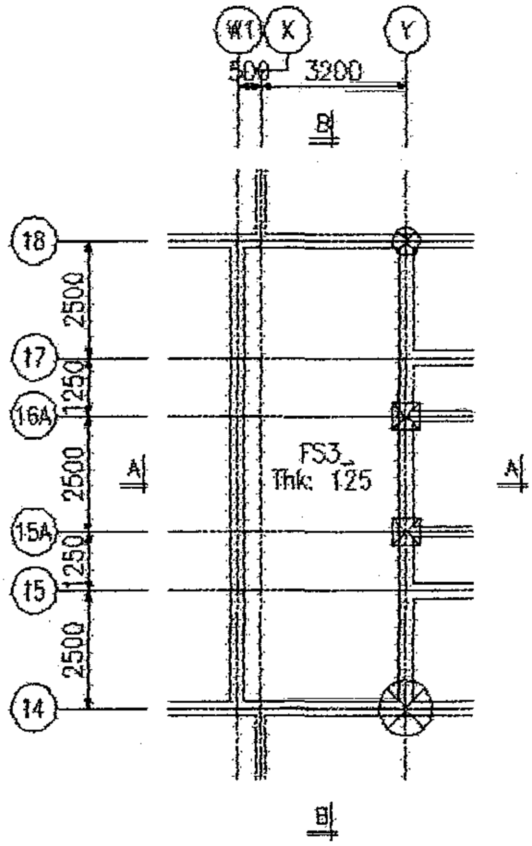


Cross-section of the Slab at A-A for Slab K-M/14-18

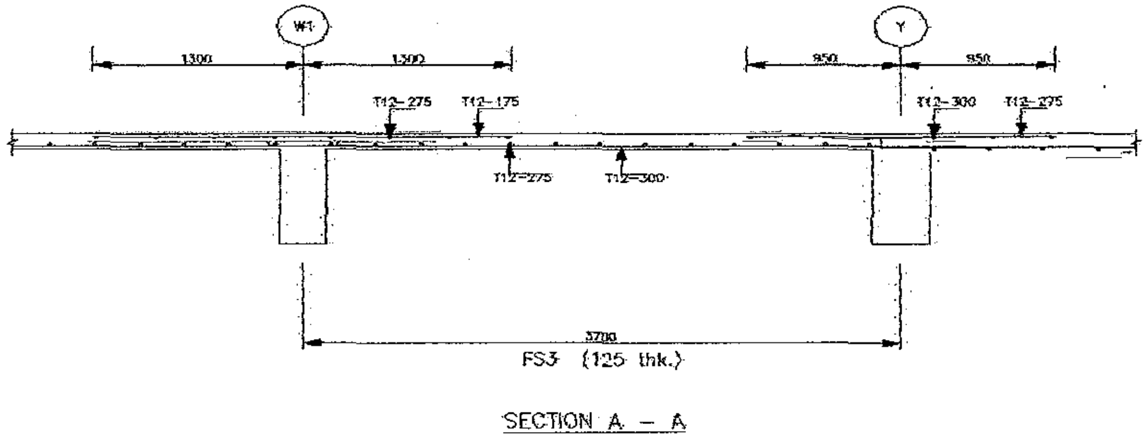


Cross-section of the Slab at B-B for Slab K-M/14-18

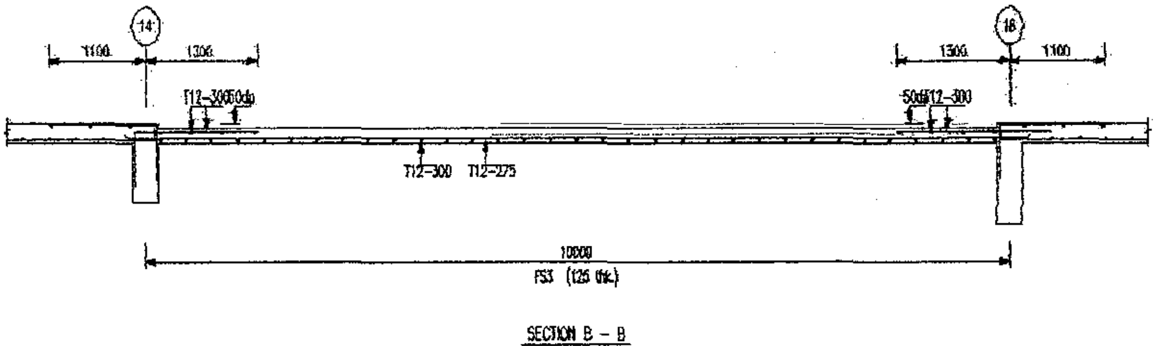
Detail drawing for Slab W1-Y / 14-18



Slab layout for Slab W1-Y/14-18



Cross-section of the Slab at A-A for Slab W1-Y/14-18



Cross-section of the Slab at B-B for Slab W1-Y/14-18

Public Assembly Occupancy Class (Halls, Auditoria, Restaurants, Museums, Libraries, Non-Residential Clubs, Theatres, Broadcasting Studios, Grandstands) (Taken from BS 6399: Part 1: 1984)

Floor Area Usage	Intensity of Distributed Load	Concentrated Load
	kN/m^2	kN
Dense mobile stacking (books) on mobile trucks	4.8 for each metre of stack height but with a minimum of 9.6	7.0
Stack rooms (books)	2.4 for each metre of stack height but with a minimum of 6.5	7.0
Boiler rooms, motor rooms, fan rooms and the like including the weight of machinery	7.5	4.5
Stages	7.5	4.5
Corridors, hallways, etc. subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like. Corridors, stairs and passageways in grandstands	5.0	4.5
Drill rooms and drill halls	5.0	9.0
Assembly areas without fixed seating*: dance halls, gymnasia, grandstands	5.0	3.6
Projection rooms, bars	5.0	-
Museum floors and art galleries for exhibition purposes	4.0	4.5
Corridors, hallways, stairs, landings, footbridges, etc.	4.0	4.5

Reading rooms with book storage, e.g. libraries	4.0	4.5
Assembly areas with fixed seating*	4.0	-
Kitchens, laundries	3.0	4.5
Chapels, churches	3.0	2.7
Reading rooms without book storage	2.5	4.5
Grids	2.5	-
Areas for equipment	2.0	1.8
Dining rooms, lounges billiard rooms	2.0	2.7
Dressing rooms	2.0	1.8
Toilet rooms	2.0	-
Balconies	Same as rooms to which they give access but with minimum of 4.0	1.5 per metre run concentrated at the outer edge
Fly galleries	4.5kN per metre run distributed uniformly over the width	-
Cat walks	-	1.0 at 1m centres