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The vibration of precast concrete elements for post-stressed bridge members

Des Vibrieren von Beton-Fertigteilen für nachträglich zusammengespannte Brückenglieder

Vibração de peças de betão prefabricadas para elementos de ponte post-esforçados

Vibration d'éléments préfabriqués pour membrures de pont précontraintes sur place

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Bridges contructed of post-stressed concrete units have certain advantages over other types of construction. The more important being the small amount of maintenance required and the possibility of manufacture at a convenient site, reducing the erection work to placing the units on a skeleton scaffold and stressing the bars or wires linking them together. These advantages are especially important in areas of rapid development such as West Africa, and areas of high rainfall requiring much maintenance of steel structures.

Concrete of high strength is always specified for this type of construction and the usual method of obtaining this high strength is to use a mix of low water content compacted with the aid of vibration. Vibration may be applied by: —

1. Vibrating tables.
2. Shutter vibrators.
3. Immersion vibrators.

All these may be used for compacting precast post-tensioned units, the method chosen depending on the weight of the casting and its dimensions. Vibrating tables are usually limited in the weight of concrete which may be compacted upon them; this is less important in the case of electro-magnetic tables since any number of these may be placed side by side to share the load and to run in phase with each other.

Mechanically driven tables owing to their inability to run in phase with controlled amplitude cannot be used in this way. Immersion and shutter vibrators are used in sufficient numbers to achieve compaction without consideration of phase difference.

The requirements are a casting which is completely homogeneous with uniform strength and modulus of elasticity throughout. Unfortunately these are rarely achieved, it is therefore proposed to examine the problem and discuss its solution.

The problem approximates to that of obtaining uniform strength throughout the casting. It has been shown elsewhere (1) that for vibrated concrete there is a minimum acceleration below which compaction does not take place. It should be emphasised that this minimum acceleration is the acceleration of the concrete and not that of the vibrating unit or mould. The minimum value of acceleration for compaction is of the order $2\,{}^1/_2$ g to 3 g dependent upon the frequency of the vibration and the workability of the mix. It may be stated therefore that to achieve full compaction throughout the casting the acceleration of every point within the casting must be equal to or exceed the minimum value.

In a large casting the acceleration at any point varies according to the distance of the point from the source of vibration and to the proximity of the side of the mould (2). Thus the lowest value of acceleration occurs near the centre of a casting vibrating on a vibrating table. It might be argued that if the acceleration at this point is greater than 3 g then all would be well. In this connection it is necessary to consider a further point. An increase in acceleration results in a reduction in the time of vibration necessary to achiéve compaction, therefore those parts of a casting having the highest acceleration will be compacted before those with a lower acceleration. It can readily be seen therefore that vibration should be continued for such time as is necessary for full compaction at the lowest acceleration.

The concrete adjacent to the sides of the mould and on the surface of the casting will have a greater acceleration than that at the centre and will be compacted first, its appearance will not then be a true indication of the completeness of vibration of all parts of the casting. If no account is taken of the foregoing then a casting may result in which the outer layers are fully compacted whilst the core is not. The conditions are analogous to a case hardened steel and the casting will not fulfill the requirements stated previously because its strength will vary. The much publicised danger of OVER VIBRATION must be considered in this context. If a mix is suitable for vibration then after full compaction has taken place no further increase in strength will result however long the period of vibration nor will it be in any way adversely affected. The troubles of overvibration and segregation only result from a badly designed mix.

Concrete mixes must be designed for vibration, the ordinary methods of design for hand placing being inadequate and in some cases harmful when applied to concrete which is to be vibrated. In addition to the segregation a further problem must be borne in mind when designing a mix, namely «Rotational instability» (3). The phenomenon is caused by one part of the mould having a slightly higher acceleration than

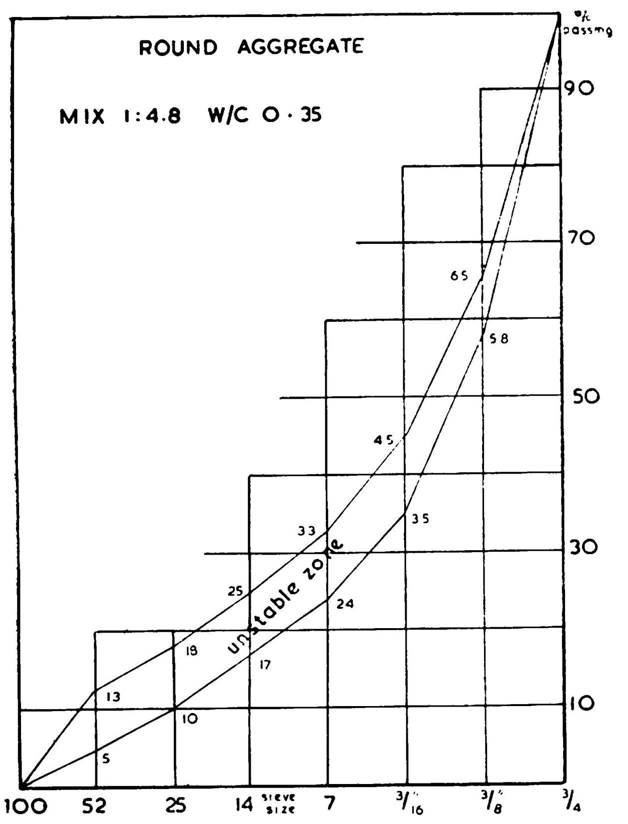

FIG. 1. Limit curve for rotational instability at accelerations up to 18 g with rounded river gravel

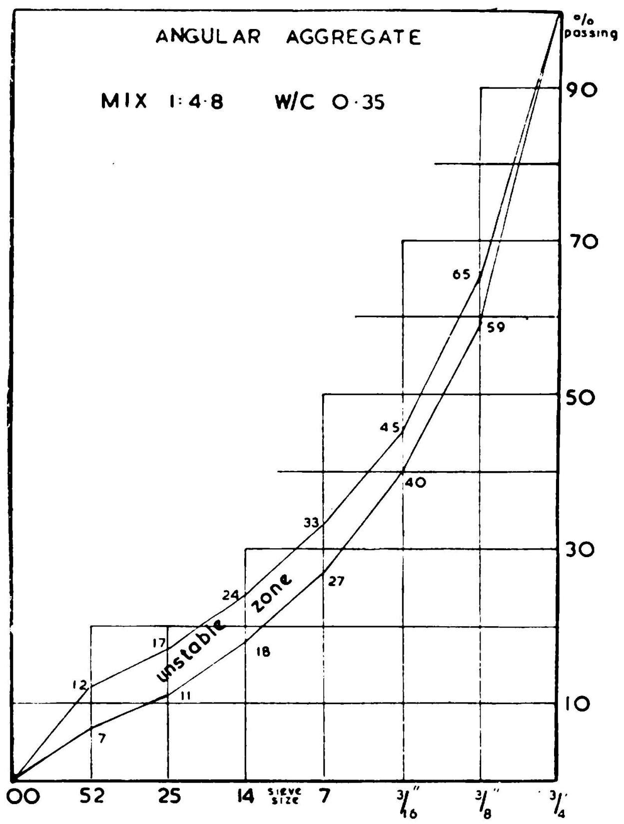

FIG. 2. Limit curve for rotational instability at accelerations up to 18 g with angular granite aggregate

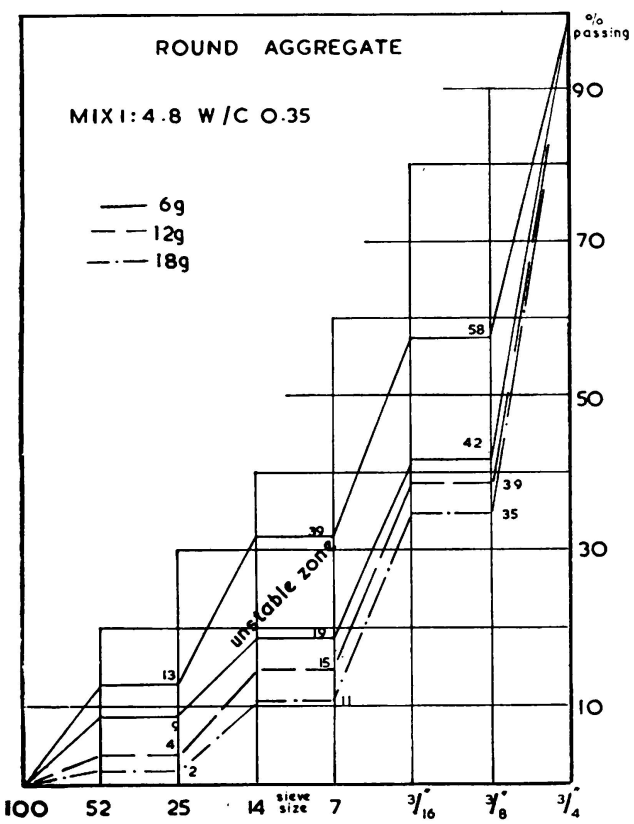

FIG. 3. Limit curve for rotational instability at accelerations up to 18 g with gap graded rounded river gravel

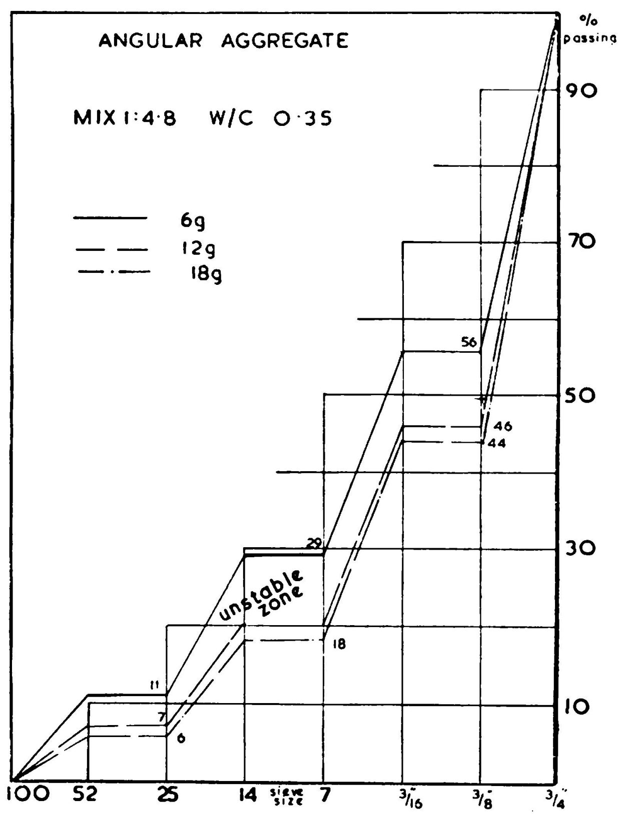

FIG. 4. Limit curve for rotational instability at accelerations up to 18 g with gap graded angular granite aggregate

other parts, in practice this, it will be agreed, is inevitable. This variation of acceleration results in a couple tending to rotate the concrete mix about a horizontal axis. If rotation does take place one part of the plastic concrete rises above the level of the remainder and a depression occurs diametrically opposite. The concrete rotates at a rate of several revolutions per minute sucking in air at the depression and forcing air hubbles into the body of the casting; compaction is never achieved and this may result in the reduction of strength by 50 % without any surface indication on the resulting casting. This phenomenon is also caused by unsuitable grading, thus the grading of a vibrated mix should be considered more closely than that for hand placed concrete. Besides considering ultimate density its internal frictional resistance must be high to eliminate Rotational instability; this may be accomplished by using the minimum quantity of fine sand i. e. that passing a N° 52 B. S. sieve.

It has frequently been claimed as an advantage of post tensioned concrete that every component is tested whilst stressing takes place. This is only partly true since only if the factor of safety of the concrete is reduced below unity does failure take place. If the strength is reduced, as it may well be, by 30 % by any of the foregoing then the stress factor of safety may be reduced from say 3 to 2 and test cubes or cylinders will not indicate such reductions since they are small enough for full compaction to be achieved under all save the most extreme conditions of instability or segregation.

The difficulties have now been described. What are the remedies?

I. Ensure that adequate power for vibration is applied to obtain an acceleration at any point in a casting greater than 3 g. A rough guide to the power required is to allow 1 watt per pound of concrete plus the energy required to vibrate the table mould etc. without any concrete (4).

II. Vibration must be continued for a sufficient time for full compaction of the whole casting. Say 120 % of the time at which the emission of bubbles from the surface ceases.

III. Design the concrete mix for vibration using fig. 1, 2, 3, or 4.

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SUMMARY

This paper considers the problems encountered in the manufacture of precast units for post tensioned bridge members of high strength with the aid of vibration. The desiderata are stated together with difficulties and the means of overcoming them to achieve the desired results.

ZUSAMMENFASSUNG

Die Arbeit behandelt die Probleme bei der Herstellung von vibrierten Fertigteilen, die später zu Brückenteilen zusammengespannt werden. Die auftretenden Schwierigkeiten sowie die Möglichkeiten zu deren Überwindung und somit zur Erreichung der gewünschten Ergebnisse werden beschrieben.

RESUMO

O autor considera os problemas relativos à fabricação, com o emprego de vibração, de elementos préfabricados para vigas de pontes de grande resistência preesforçadas no local. Indica também as condições a que devem obedecer, bem como as dificuldades, e meios de as resolver, de modo a obter os resultados procurados.

RÉSUMÉ

L'auteur considère les problemes posés par la fabrication, à l'aide de la vibration, d'éléments préfabriqués pour poutres de ponts précontraintes sur place. Il décrit les desidérata ainsi que les difficultés, et les moyens de les résoudre, pour obtenir les résultats recherchés.

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