CHAPTER 7

CONCLUSIONS

7.1 GENERAL

Extensive experimental investigations were carried out on the activation of high-calcium fly ash using lime and gypsum in mortar and concrete. Mix proportioning and the properties of F-G concrete were studied. The salient conclusions drawn based on the above are presented in this chapter.

7.2 CONCLUSIONS

Following are the salient conclusions, based on the present study:

(1) Fly ash obtained from Neyveli Lignite Corporation (NLC), Tamil Nadu, India, has substantial quantities of fine particles below 75 and 45 microns.

(2) Based on the mineralogical studies, silica and mullite along with the hematite and ferrite, have been identified as the major constituents of the above lignite-based fly ash.

(3) The lignite-based fly ash used in this study, is mainly composed of silica, alumina, iron oxides and calcium oxide (CaO) and that the presence of CaO exceeding 10% makes it to exhibit the ‘self-hardening’ property.

(4) The presence of soluble silica, gradation and fineness of the fly ash have contributed to the higher lime-reactivity of the fly ash, comparable to the highest value reported, for Indian fly ashes, by various investigators.

(5) Of the three blends, namely, fly ash – lime (F-L), fly ash – gypsum (F-G) and fly ash – lime – gypsum (F-L-G), only F-L-G and F-G blends will lead to comparable compressive strengths, in mortar. However, only F-G blend will yield the maximum compressive strength, in concrete. Hence, it is not necessary to add another activator i.e. lime (externally), to the system. Therefore, of the three blends, it is advantageous to use only F-G blend.
(6) Optimum Gypsum Content (OGC) for the F-G blend, corresponding to the maximum compressive strength of mortar/concrete is found to be in the range of 8-12 % (by weight of total binder).

(7) The compressive strength of F-G blend is found to be fairly insensitive to the two types of curing regimes (i.e. moist curing and immersed curing).

(8) The consistency and setting times (i.e. initial and final) of the F-G blends are similar to those of OPC.

(9) The maximum compressive strength of F-G mortar that could be obtained is about 16 MPa (@ 28 days, for an aggregate- binder ratio of 0.67, i.e. sand :fly ash + gypsum).

(10) The maximum compressive strength of F-G concrete that could be achieved is as high as 33 MPa (@ 28 days for a W/B ratio of 0.3) and that the minimum strength obtained is 7 MPa (@ 28 days for a W/B ratio of 0.75).

(11) Compressive strength of F-G concrete bears an inverse relationship with W/B ratio which is similar to the behavior of OPC concrete. The normalized compressive strength relationship obtained for F-G concrete, with the compressive strength at W/B = 0.5 as the reference (i.e. $S_{0.5}$) and as given below, will help to estimate the compressive strength of F-G concrete, (i.e. S) for an assumed / given W/B ratio and vice-versa.

\[
\frac{S}{S_{0.5}} = (-) 0.0177 - 3.381 \log_{10} (W/B)
\]

(12) For a particular aggregate grading and W/B ratio, the required aggregate-binder A/B ratio of F-G concrete decreases with increase in workability. The normalized aggregate-binder relationship obtained for F-G concrete, with the A/B value for low-workability as the reference (i.e. $A_{L}$) and as given below, will help to estimate the required A/B ratio (i.e. A), for an assumed/ given compaction factor ($C_f$) value and vice-versa.

\[
\frac{A}{A_{L}} = 2.699 - 1.9942 C_f
\]
(13) It was also observed that for a particular degree of workability and gradation of aggregate, the aggregate- binder (A/B) ratio is found to increase with W/B ratio. The normalized relationship for aggregate – binder ratio, with A/B corresponding to a W/B = 0.5 as the reference (i.e. A) and as given below, will help to estimate the required A/B ratio (i.e. A), for an assumed/given W/B ratio and vice-versa.

\[ \frac{A}{A_{0.5}} = (-) 0.262 + 2.495 (W/B) \]

(14) The three normalized relationships obtained for F-G concrete and given above can be used with confidence to arrive at the mix proportion corresponding to a desired compressive strength, using the procedure of re-proportioning.

(15) Of the two approaches of mix re-proportioning F-G concretes, “Approach – I” is recommended to achieve the desired strength, for a specified workability and “Approach – II” is recommended, if, W/B ratio is the design parameter. The above approaches are considered applicable for the investigated compressive strength range of 14 – 24 MPa.

(16) Statistical analysis carried out on the compressive strength of F-G concrete indicate that it is possible to obtain consistent results, even though ‘marginal materials’ have been used.

(17) Based on the various mechanical properties of F-G concrete, it is inferred that the Young’s modulus (E) and MOR of F-G concrete are about 85% and 50 %, respectively, of OPC concrete (theoretical values) and ‘E’ value of F – G concrete is about 70% of the reported ‘E’ (average) value of fly ash concrete. However, the above values of F – G are, still considerably significant.

(18) The abrasion resistance of F-G concrete satisfies the requirement of a pavement quality concrete (PQC), as stipulated in the relevant IS code.

(19) F-G concrete has higher thermal expansion and thermal conductivity, than OPC concrete, which will have a significant effect, if, it is used as a pavement material.
(20) The relationship established between the compressive strengths of 'normal curing' (\( \sigma_n \)) and 'accelerated curing' (\( \sigma_a \)) (based on IS method) and as given below, can be used to compute the 28 days compressive strength of F-G concrete (i.e. \( \sigma_n \)), based on the compressive strength obtained by 'accelerated curing' (i.e. \( \sigma_a \)).

\[
\sigma_n = 1.81451 \sigma_a
\]

(21) Of the four chemical mediums to which F-G concretes have been exposed (i.e. hydrochloric acid, acetic acid, lactic acid and magnesium sulphate), acetic acid has caused severe reduction in the 28 days compressive strength, followed by, magnesium sulphate, HCl, and lactic acid, taken in that order.

(22) F-G concrete is found to withstand a temperature upto 100\(^\circ\)C, without much appreciable loss in its compressive strength. However, it loses about 36% of its original compressive strength, when the temperature is raised to 250\(^\circ\)C, which is in line with results reported for fly ash concretes.

(23) Based on the experimental and numerical studies on F-G concrete slabs, it is concluded that F-G concrete is in fact, superior to the conventional base-course materials (i.e. like, lime-fly ash concrete, lean cement concrete and lean cement-fly ash concrete), of a road pavement. Hence, F-G concrete has the potential for use as the base or sub-base course of a road pavement and that it can be used with confidence.

(24) The following two relationships can be used to obtain the design thickness of F-G concrete either as a base or as a sub-base course, in a road pavement:

\[
\sigma_c = (-0.0483) + 0.0068 \, T
\]

\[
\Delta = 2.24 - (0.0411) \, T + 0.00213 \, T^2
\]

where, 'T' is the slab thickness (in mm); \( \sigma_c \) – contact stress (in MPa) and \( \Delta \) – the central deflection of the slab (in mm).