[0012] In a case of containing Portland cement in a hydraulic composition, a content of Portland cement in powder except for calcium carbonate ($CaCO_3$) is 70 percent by mass and below, preferably 30 percent by mass and below.

Further, in a case of using Portland cement and blast furnace slag or fly ash, for example, "Portland blast-furnace slag cement" according to JIS R5211, or "Portland fly-ash cement" according to JIS R5213 may be respectively used alone, or may be used as a mix.

[0013] The hydraulic composition according to the present embodiment, provides required strength after hardening. Further, the hydraulic composition according to the present embodiment provides reduction in CO_2 emission from a production of Portland cement by reducing cement usage or omitting Portland cement usage and stably holding and storing of CO_2 collected and absorbed from the atmosphere or exhaust gas . The hydraulic composition of the present embodiment, in which calcium carbonate ($CaCO_3$) is mixed in a highly eco-friendly hydraulic composition containing at least one selected from the group of blast furnace slag, an expansive additive, slaked lime, quick lime, fly ash and Portland cement, may prevent a reduction of strength, even though the calcium carbonate ($CaCO_3$) ratio to the quantity of powder is increased as compared to a hydraulic composition in which calcium carbonate ($CaCO_3$) is mixed in ordinary Portland cement. Further, a mix proportion containing a lot of blast furnace slag prevents a reduction of strength more.

Moreover, the hydraulic composition of the present embodiment may produce a material having excellent fire resistance since it contains a lot of calcium carbonate ($CaCO_3$). The hydraulic composition of the present embodiment has an ability of self-quenching in the event of fire since calcium carbonate ($CaCO_3$) induces an endothermic reaction: $CaCO_3 \rightarrow CaO + CO_2$, at high temperature (500 to 900 °C).

[0014] Hereinafter, experimental results conducted for hydraulic compositions of the present embodiment are described.

(1) Carbonation rates

For hardened bodies (Cases a to j) of hydraulic compositions in which calcium carbonate ($CaCO_3$) contents accounting for hydraulic compositions were 0 to 5 percent by mass and the other materials were mixed at contents described in

[0020] Then, as shown in FIG. 1, based on the comparison of Cases h, d, and f in which calcium carbonate ($CaCO_3$) were not added, carbonation rates may be higher by reducing Portland cement contents in powder except for calcium carbonate ($CaCO_3$) to 30 percent by mass and below.

On the other hand, when a calcium carbonate ($CaCO_3$) content in the total materials of a hydraulic composition (powder) is 30 percent by mass and above, regardless of the mix proportion of powder except for calcium carbonate ($CaCO_3$), a carbonation rate is expected to be equal to or greater than that of Case f in which Portland cement content was 30 percent by mass and below (the mix proportion of a case where an environmental load was intended to be reduced without using calcium carbonate ($CaCO_3$)). When a calcium carbonate ($CaCO_3$) content is 40 percent by mass and above, regardless of the mix proportion of powder except for calcium carbonate ($CaCO_3$), a carbonation rate is expected to be equal to or greater than that of Case d in which a Portland cement content was 30 percent by mass and below (the mix proportion of a case where an environmental load was intended to be reduced without using calcium carbonate ($CaCO_3$)).

Therefore, 30 percent by mass and above, preferably 40 percent by mass and above, of a calcium carbonate ($CaCO_3$) content in powder provides an effect equal to or greater than an effect of a case where Portland cement content in powder reduces, regardless of the components of a powder except for calcium carbonate ($CaCO_3$).

In this way, it was confirmed that a hydraulic composition with a high carbonation rate may be expected to take CO_2 from the atmosphere a lot more and to increase the amount of CO_2 to be absorbed during a use.

[0021] Comparing Cases c, g, e and j in which calcium carbonate ($CaCO_3$) contents accounting for respective hydraulic compositions were equal to each other, carbonation rates tended to be high when blast furnace slag contents accounting for a hydraulic composition increased (namely when blast furnace slag contents accounting for powder except for calcium carbonate ($CaCO_3$) increased). Therefore, when blast furnace slag is contained in a hydraulic composition, a blast furnace slag content accounting for powder except for calcium carbonate ($CaCO_3$) is better to be high in a powder except for calcium carbonate ($CaCO_3$) (namely, blast furnace slag, Portland cement, an expansive

approximate lines are for measurement points where calcium carbonate ($CaCO_3$) contents accounting for respective hydraulic compositions were 50 percent by mass and more and effects on the strength were detected. Straight line i indicates a case where Portland cement content accounting for powder except for calcium carbonate ($CaCO_3$) was 100 percent by mass, straight lines ii, iii, and iv indicate cases where Portland cement contents accounting for powder except for calcium carbonate ($CaCO_3$) were 30 percent by mass, 15 percent by mass and 0 percent by mass, respectively. As straight lines i to iii in FIG.2 indicate, increasing rates of strength to increases of quantities of cement per unit volume were higher as Portland cement contents accounting for powder except for calcium carbonate ($CaCO_3$) were lower. Therefore, using blast furnace slag, an expansive additive, slaked lime and fly ash as powder except for calcium carbonate ($CaCO_3$) and decreasing a Portland cement content provide an extraordinary effect of elevating compressive strength without a large increase of a quantity of cement per unit volume.

[0030] FIG. 3 is a graphical representation of compressive strength ratios at 28 days (28d) indicated in Table 4. As shown in FIG. 2, FIG. 3 and Table 4, in cases where calcium carbonate ($CaCO_3$) contents were 25 percent by mass (cases 1-25, 2-25, 3-25, and 4-25), the compressive strengths were lower than those of cases A-25 and B-25 where calcium carbonate ($CaCO_3$) and Portland cement only existed. On the other hand, in cases where calcium carbonate ($CaCO_3$) contents were 50 percent by mass and more (cases 1-50, 1-70, 1-90, 2-50, 2-70, 2-90, 3-70 and 4-70), the compressive strengths were higher than those of cases A-50, A-70, A-90, B-50 and B-70 where calcium carbonate ($CaCO_3$) and Portland cement only existed. Namely, a compressive strength ratio is possibly over 1 when a calcium carbonate ($CaCO_3$) content is over 25 percent by mass, and FIG. 3 indicates that a compressive strength ratio was over 1 when a calcium carbonate ($CaCO_3$) content was over 30 percent by mass. Therefore, even when Portland cement is switched to a material using at least one selected from blast furnace slag, an expansive additive, slaked lime, quick lime, and fly ash , if a calcium carbonate ($CaCO_3$) content accounting for a hydraulic composition is 30 percent by mass and more, strength equal to or more than that of a hydraulic composition mix material containing only calcium carbonate ($CaCO_3$) and Portland cement is exerted. Since a compressive strength ratio was over 1.2 generally when a calcium carbonate

hydration activity, even when a calcium carbonate ($CaCO_3$) content was high as 46.4 percent by mass, compressive strength securely remained 40 N/mm^2 and more. Further, in addition to flexural strength, increase of compressive strength is expected by adding steel fibers. For example, although Example 72 was substantially the same as the material in which a steel fiber was added to Example 66 (refer to Table 11), the compressive strength of Example 66 that didn't have a steel fiber was 34 N/mm^2 at a material age of 28 days, while the compressive strength of Example 72 that had a steel fiber was 43 N/mm^2 at a material age of 28 days.

These results indicate that even hydraulic composition mixed materials having a high calcium carbonate ($CaCO_3$) content accounting for a hydraulic composition and being added a fiber material may produce concrete having the same workability and the same compressive strength as that of ordinal fiber-reinforced concrete.

[0064] (8) Effects of polishing

Next, for a hardened body of a hydraulic composition mixed material containing a hydraulic composition of the present embodiment, a fine aggregate, and a coarse aggregate, the effect of polishing the surface of the hardened body was examined. The hydraulic composition mixed material described below had a calcium carbonate ($CaCO_3$) content accounting for a hydraulic composition of 41.3 percent by mass. Water was added to a hydraulic composition mixed material (a hydraulic composition, a fine aggregate, and a coarse aggregate) and mixed, the mixture was poured into a mold and cured, then a prism specimen of 15 cm x 15 cm x 1cm thick was prepared. The prepared specimen was applied for sealed curing outside (the outside temperature of 0 to 7 °C) up to 14 days of a material age followed by demolding, then polished by using a polisher for stone materials with a grit of # 400. The mix proportion was shown in Table 15.

[0065] Note that, for the experiments, materials described below were used.

Water : tap water

Blast furnace slag : ground granulated blast furnace slag 4000, a density of 2.89 g/cm^3, a Blaine specific surface area of 4480 cm^2/g, JIS A6206

Expansive additive : expansive additive type 30 (lime-based expansive additive), a density of 3.15 g/cm^3, a Blaine specific surface area of 3810 cm^2/g,