

中華民國第 54 屆中小學科學展覽會 作品說明書

高職組 土木科

佳作

最佳團隊合作獎

091201

還以顏色一百年預彩工法

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關鍵詞：混凝土、建築材料、色料

摘要

放眼看去台灣的建築結構外觀，大部分都是磁磚、玻璃帷幕或者是油漆為主，因此外觀的色彩有限，為了擴大台灣建築色彩生活美學、想像空間與環境美化，創造在地建築人文景觀，運用不同色彩的搭配，使混凝土建築物外觀不再只是單調素材，令人覺得枯燥乏味，而是能與光線能量結合，使人耳目一新的色彩。對於無法使用水泥漆、磁磚或不易維護場所非常適合。本研究以建築傳統工法加以改良，水泥砂漿、混凝土中加入色料，使結構體色彩豐富，並探討後續抗壓、抗拉強度、耐久性、耐光、耐氣候潮濕變化……等問題，期許能節省人力、時間、降低成本，以提高工作效率，減短施工工期，如果建築物能夠多樣化、色彩更豐富，相信台灣的建築業會更加多彩多姿。

壹、研究動機

在建築工程中，一棟好的建築物除了要具備好的設計感，堅固耐用的材料，建築物外觀也是一項不可或缺的因素。建築物外觀是給人第一眼最重要的印象，而多半的建築物外觀採用磁磚、石材或玻璃帷幕牆，因磁磚及石材為施工較方便的建材。但經過日積月累時間的摧殘，使建築物外觀的磁磚剝落、髒污，甚至可能砸傷路人、危害路人安全（如圖 1-1、1-2）。室內也因為潮濕導致水泥漆或油漆剝落現象產生（如圖 1-3、1-4）。因此本研究針對在混凝土及水泥砂漿中加入著色劑，製作出彩色混凝土及水泥砂漿，如此一來，建築物灌製混凝土完畢後，表面就不須作任何裝飾而能夠達到豐富色彩的結構主體，或是彩色水泥砂漿粉刷牆面後不用再粉刷或油漆，進一步達到節能、環保、安全零污染、無化學刺激等的要求條件。



圖 1-1



圖 1-2

圖 1-1、1-2 磁磚因過於老舊而剝落、髒污實例



圖 1-3



圖 1-4

圖 1-3、1-4 水泥漆、油漆因過於老舊而剝落、髒污實例

貳、研究目的

實驗混凝土材料與各種色料混合的情形，做出水泥砂漿與色料混合的色塊。運用不同色料的配比，加以浸水養護後觀察是否會褪色與掉色，並且以最低的成本創造出與眾不同的混凝土及水泥砂漿，替代部分牆面粉刷、外牆美化等所需要的建材並利用回收材料創造出更多應用想像空間，如：水泥漆、磁磚、玻璃……以減少製造成本、施工時的污染與耗材，以達到節能減碳環保愛地球，創造台灣未來建築色彩景觀（如圖 2-1、2-2、2-3）。



圖 2-1（拍攝地點：德國）



圖 2-2（拍攝地點：德國）



圖 2-3

（圖 2-1、2-2、2-3）建築物外牆在灌製混凝土時，將色料加入至混凝土中，形成彩色混凝土，混凝土直接灌製完成後，就無需再使用其他外牆上的裝飾，如此不但能減少成本，還能縮短工期，更能增加建築物的美觀，若有髒污，只需用高壓水柱清刷即可，真是一舉數得（如圖 2-4）。



圖 2-4 清洗前

清洗後

圖 2-4 地面色磚清洗前後顏色差異（拍攝地點：汐止）

參、研究設備及器材

一、研究設備

<p>電子秤</p> 	<p>10*20 圓柱試體模</p> 	<p>抗拉試體模</p> 
<p>5*5*5 抗壓試體模</p> 	<p>抗拉試驗機</p> 	<p>萬能試驗機</p> 
<p>線鋸機</p> 	<p>圓鋸機</p> 	

二、研究材料

<p>卜特蘭水泥 I 型</p> 	<p>白水泥</p> 	<p>金鋼砂</p> 
<p>一般砂</p> 	<p>石材</p> 	<p>石英砂</p> 
<p>木模</p> 	<p>紅色有機顏料</p>  <p>型號 Heuco Red 300204</p>	<p>黃色有機色料</p>  <p>型號 Vynamon Yellow 113901</p>

紅色無機色料



型號 Tico Red 652

綠色無機色料



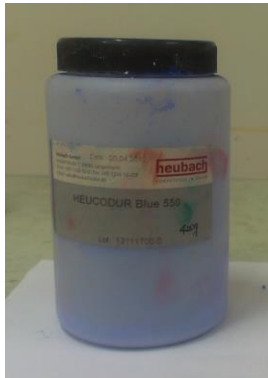
型號 Heucodur Green 654

暗紅色無機色料

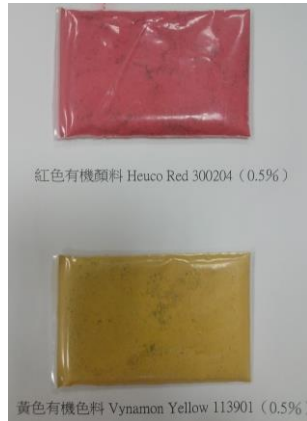


型號 Colortherm Red 120M

藍色無機色料



型號 Heucodur Blue 550



紅色、黃色有機色料
彩色水泥 (0.5%)



綠色無機色料彩色水泥
(0.5%)



藍色無機色料彩色水泥
(0.5%)



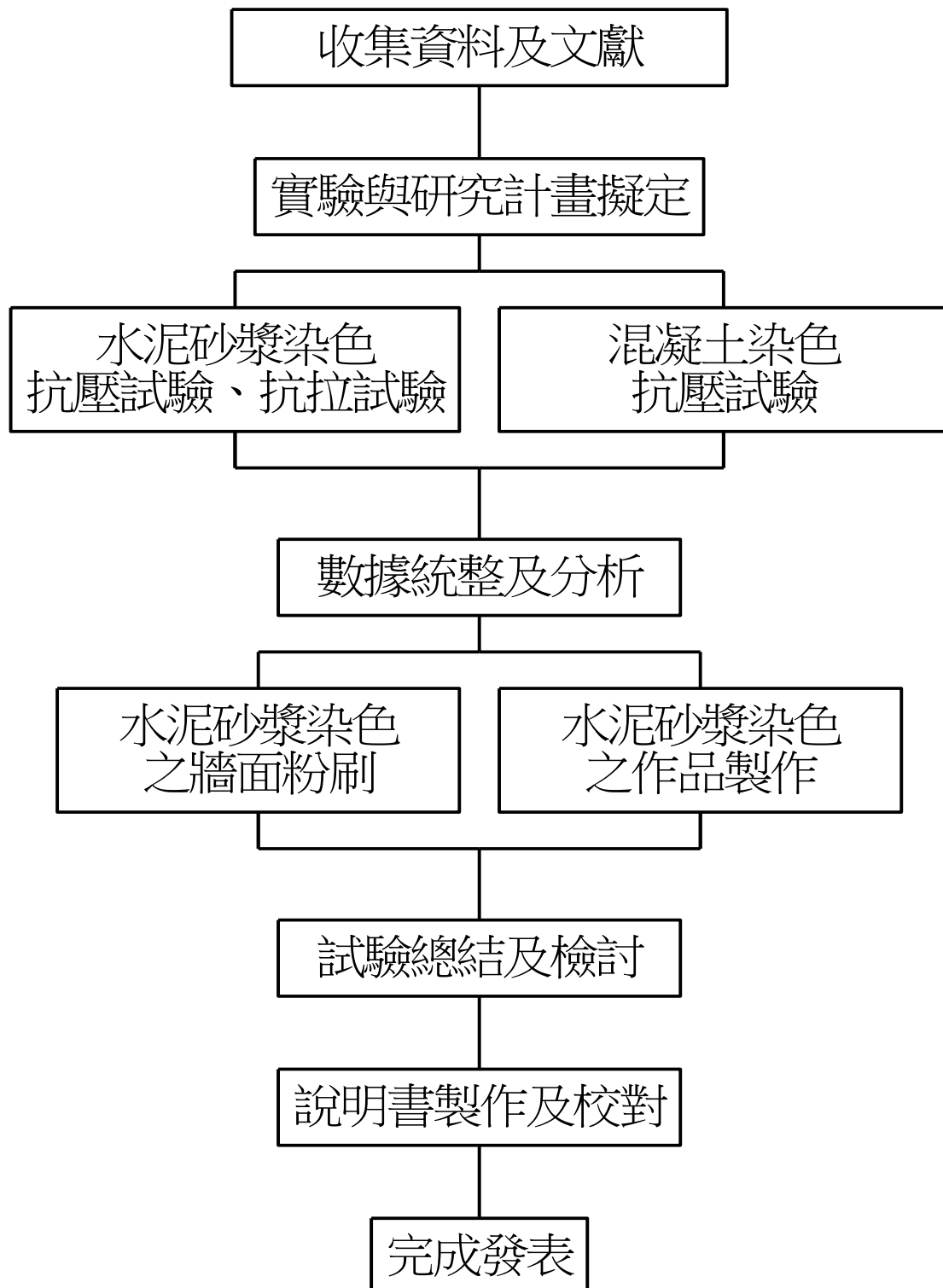
亮紅色無機色料彩色水泥
(0.5%)



暗紅色無機色料彩色水泥
(0.5%)

肆、研究過程或方法

一、研究過程



二、研究方法

(一) 色料選用

凡事總是起頭難，一開始我們要先決定使用何種色料、有何差異、國內與國外之差別，因此上網查詢了許多的資料以及收集了各式各樣的色料顏色及廠牌，但經過多次的實驗比較之後，最後選用的是德國進口的色料，而德國進口的色料又分為有機色料和無機色料。剛開始選用有機色料，但經過多次實驗後，發現有機色料不溶於水，且無法與水泥均勻混合，即使採用高速震動或用塑膠袋摩擦均勻之方式，仍無法均勻混合，因此顏料會沾於手上，浮於水面，顏色也會隨著時間而褪色（如圖 4-1、4-2、4-3）。



圖 4-1



圖 4-2

三個月後



圖 4-3

（如圖 4-1）紅色有機色料製作而成的水泥砂漿色塊均勻分布、無褪色的問題，但因溶解色料時須用到調墨油，而調墨油是屬於化學產品，當中含有有害人體物質，而且造成水泥砂漿結構脆弱，因此嚴重影響到水泥砂漿抗壓強度，故無法使用於後續研究。

黃色有機色料製作而成的水泥砂漿色塊分布均勻（如圖 4-2），但經過風吹日曬、放置一段時間後逐漸褪色，同一物品到最後卻沒有色料殘留於水泥砂漿表面上，故無法使用於後續研究（如圖 4-3）。

經歷過有機色料的失敗，為了確保色料的實用性及準確度，我們決定使用的是德國進口之無毒又環保之無機色料，以作為這次研究使用，顏色依然使用紅、藍、綠三種基本色系（無毒證明書詳見附錄一）。

(二) 水泥砂漿試體配比設定及製作：

1、石英砂與金鋼砂之說明：

(1) 石英砂是石英石經破碎加工而成的石英顆粒。是一種質地堅硬、耐磨、化學性質穩定的矽酸鹽類礦物。其主要礦物成分是 SiO_2 ，石英砂的顏色為乳白色、或

無色半透明狀，硬度7，密度為2.65，不溶於酸，微溶於KOH溶液，熔點1750℃。

(2) 碳化矽又稱金鋼砂或耐火砂。碳化矽是用石英砂、石油焦（或煤焦）、木屑（生產綠色碳化矽時需要加食鹽）等原料在電阻爐內經高溫冶煉而成。比重為3.20~3.25，硬度是9.5。

2、抗壓試體製作：

一般砂、金鋼砂、石英砂各製作一組水泥砂漿之標準配比1：2.75，水灰比0.4，流度值為0.58。

一般砂、金鋼砂、石英砂各製作一組染色水泥砂漿之標準配比1：2.75，**顏料占水泥重量0.5%**，水灰比0.4，流度值為0.58。

3、抗拉試體製作：

一般砂、金鋼砂、石英砂各製作一組水泥砂漿之標準配比1：3，水灰比0.4，流度值為0.58。

一般砂、金鋼砂、石英砂各製作一組染色水泥砂漿之標準配比1：3，**顏料占水泥重量0.5%**，水灰比0.4，流度值為0.58。

(三) 作品木模釘製：

先確定作品尺寸並複製到木板上且標示記號，將做完記號的木板利用線鋸機、圓鋸機、鋸子一塊塊切割完畢後，最後把木板一片片釘製成設計之形狀，即完成木模。

(四) 開始製作試體：

先將試體原料分別計算重量，再利用電子秤將試體的配比稱重，分別作成混凝土圓柱試體、水泥砂漿抗壓試體以及抗拉試體。

(五) 簡易試體養護：

先將儲水桶內裝入足以將所有試體沒入水中的量，再將石灰粉倒入桶內，均勻攪拌使其液體達至飽和狀態，作為試體的養護液。

(六) 試體抗壓、抗拉強度測試：

依 28 天齡期養護後，將試體陸續放進萬能試驗機、抗拉試驗機內進行抗壓、抗拉強度之實驗。同時記錄下實驗數據，計算出每一試體的抗壓、抗拉強度。

三、作品製作過程



步驟一

木模裁切、釘製



步驟二

木模製作完成



步驟三

依照配比混合原料



步驟四

拌合完成後放入木模
中加入鐵絲增加強度



步驟五

震動木模使水泥砂漿
中空氣跑出



步驟六

使用船型鏟刀將表面
抹平



步驟七

鑄模完成



步驟八

作品放入飽和石灰水
中養護

四、各式抗壓、抗拉試體及試驗

(一) 水泥砂漿、混凝土抗壓強度試驗 (此試驗參考ASTM C 109 , CNS 1011)

試驗目的：本方法係用測定之水泥砂漿、混凝土抗壓強度

試驗步驟：

- 1.將試體於水中取出，並拭乾表面並修飾
- 2.置試體於抗壓試驗機中央，注意試體與儀器接觸之上下兩面不得使用墊板。
- 3.加負荷於試體上在20~80秒內加至3000磅 (13.3KN) 負荷增加率於試體上。
- 4.記錄其最大荷重質。

計算結果： $Sc=P/A$ (Kg/ cm²)

P=最大荷重 (Kg)

A=面積 (cm²)

(二) 水泥砂漿、混凝土抗拉強度試驗 (此試驗參考ASTM C 109 , CNS 1011)

試驗目的：本方法係用測定之水泥砂漿、混凝土抗拉強度

試驗步驟：

- 1.將試體於水中取出，並拭乾表面並修飾
- 2.將試體置入試驗機之夾頭內，以每分鐘 2.67 ± 0.11 KN (600±2.5 磅) 之負荷連續增加至試體破裂為止。
- 3.測量破壞時所需之力。

計算結果： $Sc=P/A$ (Kg/ cm²)

P=作用力 (Kg)

A=破壞處之斷面積 (cm²)



混凝土圓柱抗壓試體



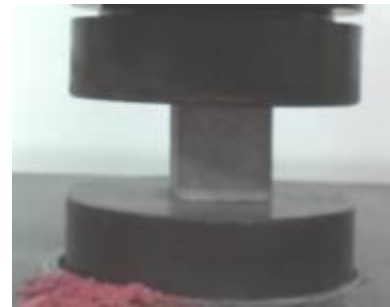
水泥砂漿抗壓試體



水泥砂漿抗拉試體



水泥砂漿抗拉試驗



水泥砂漿抗壓試驗



混凝土圓柱抗壓試驗

五、作品實例



圖 4-4

（如圖 4-4）作品是利用預鑄加預彩的施工方式，由四塊 40cm*30cm、四種不同顏色的水泥砂漿色塊所拚貼而成，鮮豔的顏色加上強烈的對比，給人的視覺感受耳目一新，拼貼完成後極適用於園藝造景、室外地板，若加上不同的標誌及文字極具吸引目光且更快速地傳達訊息。

六、粉刷實例



圖 4-6



圖 4-7



圖 4-8

（如圖 4-6、4-7、4-8）利用彩色水泥砂漿粉刷出各式各樣不同風格的感覺，但在施作的過程中因技術不夠純熟、方法不夠熟練，導致出現裂縫、粉刷不平整的問題，此作品的目的是為了嘗試取代水泥漆在室內的粉刷，因為取代了水泥漆就能夠節省下不少成本，也能減少因製作水泥漆對環境的污染及有機揮發性物質（VOC）對人體的影響，能夠達成節能減碳的功效。

伍、研究結果

水泥砂漿及混凝土 28 天抗壓、抗拉強度結果，用來比較染色前及染色後的抗拉、抗壓強度變化，確保色料加至水泥中並不會影響水泥砂漿或混凝土的強度及其特性。

一般砂染色前後之抗壓強度（如圖 5-1）

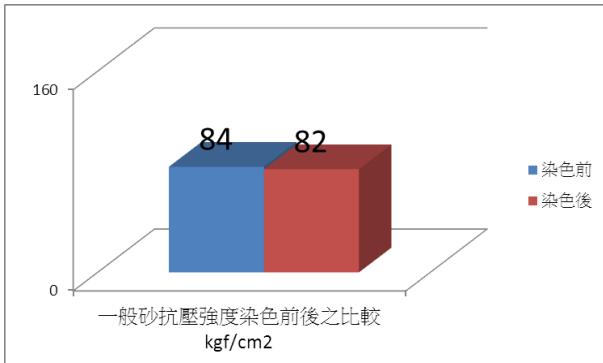


圖 5-1

一般砂染色前後之抗拉強度（如圖 5-2）

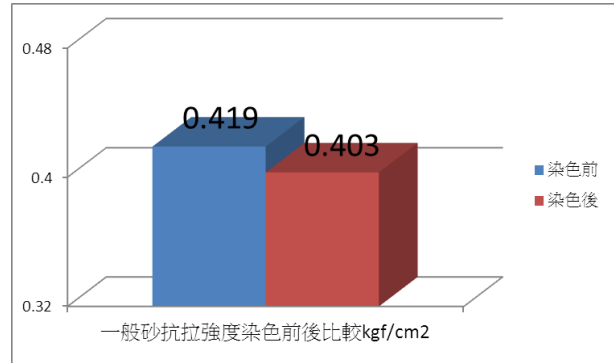


圖 5-2

鋼砂染色前後之抗壓強度（如圖 5-3）

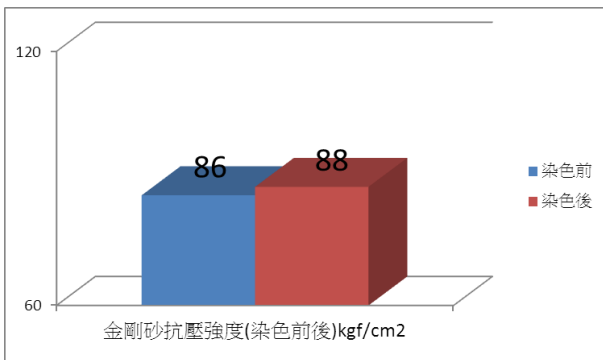


圖 5-3

金鋼砂染色前後之抗拉強度（如圖 5-4）

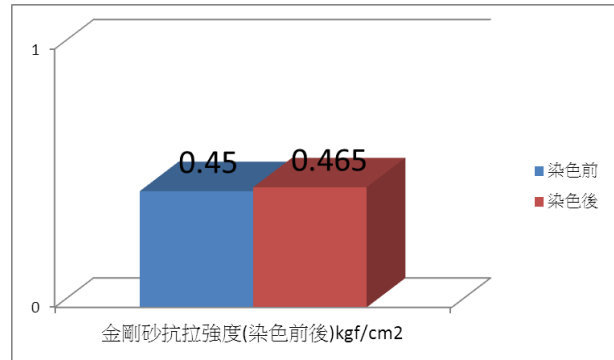


圖 5-4

石英砂染色前後之抗壓強度（如圖 5-5）

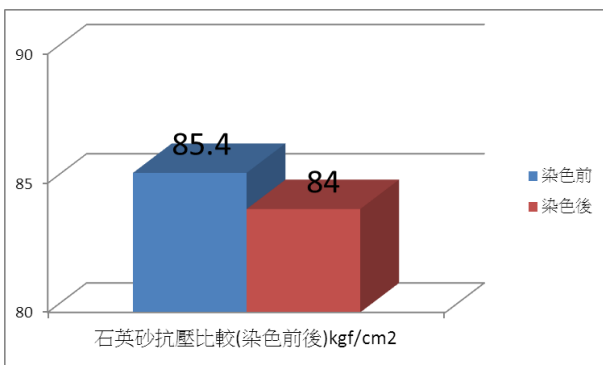


圖 5-5

石英砂染色前後之抗拉強度（如圖 5-6）

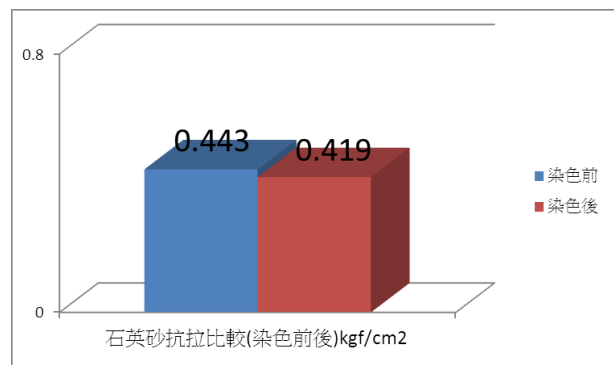


圖 5-6

一般砂、金鋼砂、石英砂染色前
之抗壓強度 (如圖 5-7)

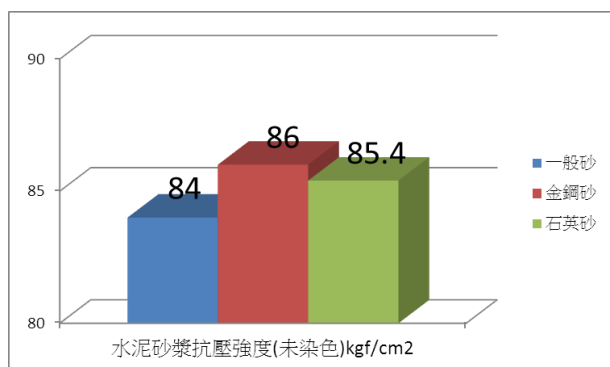


圖 5-7

一般砂、金鋼砂、石英砂染色後
之抗壓強度 (如圖 5-8)

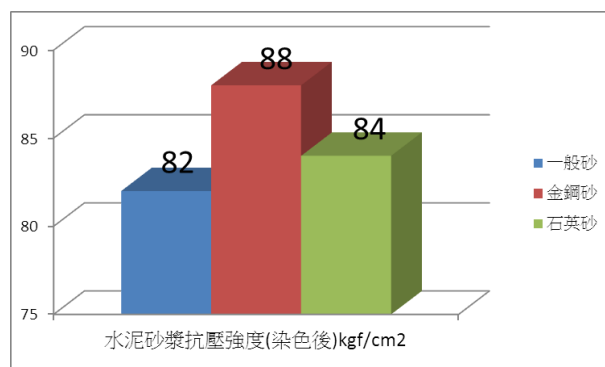


圖 5-8

一般砂、金鋼砂、石英砂
水泥砂漿染色前之抗拉強度 (如圖 5-9)

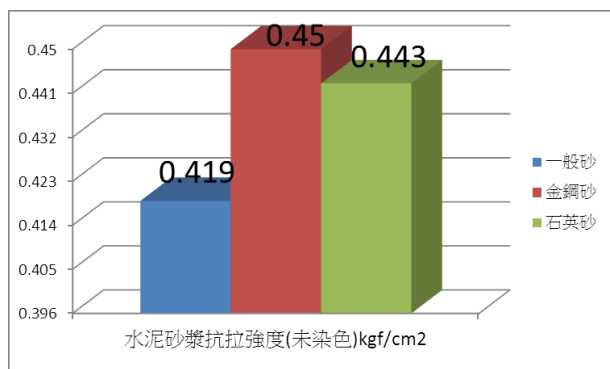


圖 5-9

一般砂、金鋼砂、石英砂
水泥砂漿染色後之抗拉強度 (如圖 5-10)

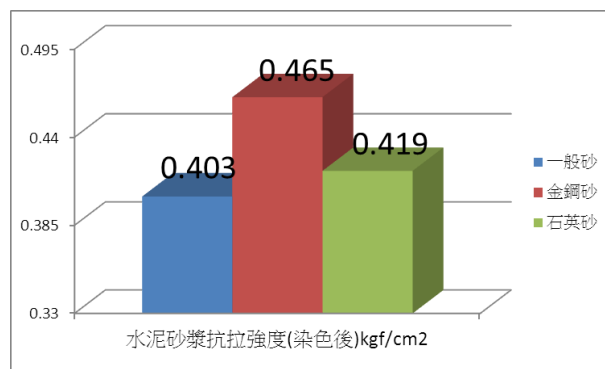


圖 5-10

一般砂、金鋼砂、石英砂
混凝土染色前後之抗壓強度 (如圖 5-10)

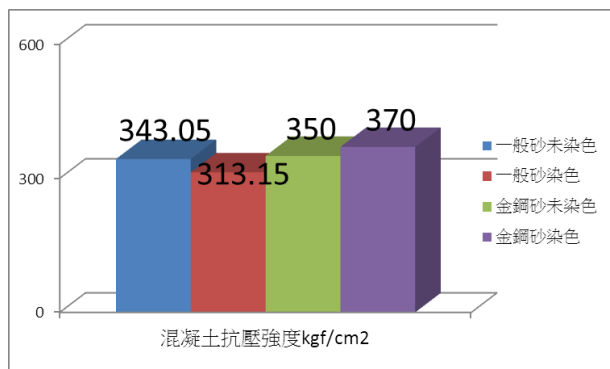


圖 5-10

水泥砂漿抗壓強度試驗數值（表 5-1）

表 5-1

	染色前 (kgf/cm ²)	染色後 (kgf/cm ²)
一般砂	84	82
石英砂	85.4	84
金鋼砂	86	88

水泥砂漿抗拉強度試驗數值（表 5-2）

表 5-2

	染色前 (kgf/cm ²)	染色後 (kgf/cm ²)
一般砂	0.419	0.403
石英砂	0.443	0.419
金鋼砂	0.45	0.465

混凝土抗壓強度試驗數值（表 5-3）

表 5-3

	染色前 (kgf/cm ²)	染色後 (kgf/cm ²)
一般砂	343.05	313.15
金鋼砂	350	370

由這些試驗強度比較圖表，發現混凝土與水泥砂漿在加入色料前後，強度並沒有太大的差異變化，因此無須擔心在混凝土或水泥砂漿中加入色料後會影響強度的問題。

陸、討論

一開始實驗的過程中不懂配比不同所造成的影響，上了工程材料這門課後才深入了解，水灰比對水泥砂漿、混凝土的重要性，以及製作抗壓、抗拉試體的步驟與相關知識，開始製作水泥砂漿試體時，發現每種不同材料的性質有所差異，石英砂質地較細緻、拌合容易，金鋼砂本身不吸水，因此水灰比較其中兩者低，加上本身硬度較高之緣故，抗壓強度最高，其次分別為石英砂、一般砂。而染色前及染色後的抗壓及抗拉強度並沒有因為添加顏料而有很大的變化，因此可使用在建築物主體結構上。在水泥染色上，運用不同比例調配出深淺之色差，使顏色變化能更多元化。

透過此項研究得知預彩工法的優缺點及限制，優勢是我們想要的，但是它的缺點及限制也希望能深入的了解與克服，以下將針對彩色水泥之缺點及限制兩方面加以討論：

一、缺點

- (一)、由於是整體灌注混凝土，外牆無法像貼磁磚或是油漆如此之華麗細膩，也不像金屬帷幕牆般炫耀，相對的顏色較樸實、回歸自然。
- (二)、施工時會因品質問題影響牆面美觀與否。

二、限制要求為” 素材及施工方法”

因建築物多使用灰水泥，但加入色料後無法完整呈現色料本身顏色，而白水泥與色料結合後能夠完整呈現出色料本身顏色，較適合使用。砂子方面不管是使用一般砂、石英砂、金鋼砂皆適合。故建議採用清水模或預鑄加預彩的施工方式，而清水模之施工特色介紹如下。

(一)、清水模介紹

清水模除了外觀具有美感之外，拆模之後即為完成作品，表面不再粉刷或貼磁磚，可以減少材料的使用和垃圾的產生，而且清水混凝土對品質的要求比一般 RC 混凝土高，所以強度也比較好，還有良好的通透性，所以清水模是減少污染、耐久、節能的環保建材。但由於施工不易，因此在選用建材時，還是要好好的考慮經濟能力是否可以負擔？

下方介紹為清水模建築案例：

北投法鼓山農禪寺水月道場

整個建築外觀設計上以莊重大氣的清水混凝土為主，依據聖嚴法師水中月空花的意念設計而成（如右圖）。



(二)、傳統灌注混凝土和清水模灌注混凝土之工法比較，如表 6-1。

表 6-1

	傳統灌製混凝土工法	清水模混凝土工法
拆模後外觀	粗糙又斑駁	平滑又色澤一致
混凝土性質	一般	工作性較高的混凝土
技術	技術性低	技術性高
建築外牆	需貼磁磚或粉刷	不需要，自身質樸素雅
相關零件	不需特殊零件	需要眾多配套零件
養護	養護簡單容易	養護要求嚴謹又繁複
日後維修費用	容易有剝落髒污維護費用高	若有髒汙以強力水柱清洗即可
施工前後過程	灌製結束須作外牆美化	每個環節都須多加注意

在建築工地中，最大的污染源來自粉刷，包括廢棄物及空氣汙染，清水模由於模板拆除後不能粉刷，也不能修改，因此減少許多不必要的裝飾和工料耗損，更符合環保原則。而適合與清水模搭配的建材，幾乎都是自然環保的材料，所以有越來越多的綠建築設計選擇使用清水模工法，清水模的環保概念已經逐漸受到各界的關注。

三、成本分析：

成本的節省與否是一個很重要關鍵，經過實地詢價、訪問，以下是材料價格及工資、施作面積的分析

(一)、工料分析：

1：3 水泥砂漿用量的工料分析一般標準

每 m^3 材料須用量：

50 公斤水泥 9 包，砂為 $0.95m^3$

若粉刷厚度為 1.5 公分

水泥每 m^2 用量 $50*9*0.015=6.75$ 公斤

砂每 m^2 用量 $0.95*0.015=0.01425$ 立方

1：2 水泥砂漿用量的工料分析一般標準

每 m^3 材料須用量：

若 50 公斤水泥 13 包，砂為 $0.8m^3$

若粉刷厚度為 1.5 公分

水泥每 m^2 用量 $50*13*0.015=9.75$ 公斤

砂每 m^2 用量 $0.8*0.015=0.01$ 立方

染色顏料 (1KG) 300 元

水泥漆 (100ml) 225 元

二丁掛磁磚 ($1m^2$) 1400 元

水泥 (1KG) 25 元

砂子 ($1m^3$) 450 元

(二) 工資分析：

粉刷工：上午施作（250cm*300cm）、下午施作（250cm*300cm） 一天約施作 15m²

水泥漆工工資（一天 2800 元） 磁磚工工資（一天 2800 元） 粉刷工工資（一天 3000 元）

室內牆面成本比較表

呈現方式	水泥漆	彩色水泥
工資（一天施作 15m ² ）	粉刷工（3000+3000 元） （註一）+水泥漆工 （2800 元）=8800 元	粉刷工（3000+3000 元） （註一）
材料成本 （15m ² ）	1:3 水泥砂漿 2835+315 元 1:2 水泥砂漿 4095+270 元 水泥漆（200ml）450 元	1:3 水泥砂漿 2835+315 元 1:2 水泥砂漿 4095+270 元 染色顏料占全部水泥 總重 0.5%、49g、15 元
總成本	16765	13530

室外牆面成本比較表

呈現方式	二丁掛磁磚	彩色水泥
工資（一天施作 十五m ² ）	粉刷工（3000+3000 元） （註一）+磁磚工（2800 元）=8800 元	粉刷工（3000+3000 元） （註一）
材料成本 （十五m ² ）	1:3 水泥砂漿 2835+315 元 1:2 水泥砂漿 4095+270 元 二丁掛磁磚 6000 元	1:3 水泥砂漿 2835+315 元 1:2 水泥砂漿 4095+270 元 染色顏料占全部水泥 總重 0.5%、49g、15 元
總成本	22315	13530

註一：粉刷需先打底層（1：3 水泥砂漿）等待乾燥後再粉刷（1：2 水泥砂漿），因此工期需要 2 天、工資 6000 元

（三）成本比較分析：

依據我們收集的資料以及計算出來的數據，比較出彩色水泥比一般的水泥漆及磁磚節省了近乎一倍的成本，而且水泥漆及磁磚必須等到底層水泥砂漿乾了之後才能加以施作，而彩色水泥卻能夠直接的粉刷，完成後就不必做任何裝飾，因此能減少一半的工期。

柒、結論

色料與水泥材質的專業與技術性選擇和設計是這個研究成敗關鍵，它的成功會體現在大面積的均一品質、較高的彩度與廣泛柔和色調的出現，因此，得到以下結論：

一、材料選擇

凡是做實驗的材料都需要經過嘗試後才了解材料的性質及優劣，但材料也會因為目的的不同而產生優劣，例如我們在剛開始使用有機色料時，發現它的性質與我們所需的性質截然不同，因為有機色料能夠運用在彩妝、塑膠、印刷等方面，所以我們才會嘗試溶入水泥砂漿中，但得到的結果卻是無法與水泥砂漿混合，在這之後轉換成無機色料，發現性質非常相近，因此採用了無機色料作為後續研究。

二、拌合過程

選擇先和水泥混合的原因是因為試驗的過程是用人工拌合方式，所以要先將色料與水泥確實混合，及增加色料的展性使色料的顏色均勻的呈現出來。但因施工方式不同而拌合方法亦不同，例如機械式拌合可先讓砂與水泥混合再加入色料，主要因機械拌合方式能夠高速又均勻的拌合，使色料展現出原有的色彩，因此，拌合過程不管是手工或機械，以能夠完全混合均勻為首要條件。

三、實驗過程分析

有別於一般人對於混凝土的刻板印象，作品中運用不同顏色的色料及色料百分比不同添加至混凝土中，拋磚引玉式的實驗過程使作品呈現各式各樣、不同深淺的顏色與色階，同時又不影響混凝土的強度及特性。在進行一連串的實驗之後，證實了混凝土與水泥砂漿加入了色料不會降低本身的強度，並能帶給建築物不一樣的外觀，可注入許多色彩讓建築物的設計方式更加多元化，使人們不再會為了建築物的外牆而煩惱。

四、成本

節省成本在我們這次的研究中也是主要問題之一，根據調查發現外牆粉刷的成本甚高，所以希望能夠製作出低成本又能代替水泥漆、油漆以及磁磚等……的外牆，因此這次的過程中研究出如何有效的減少成本的工法。因為已減少一道工序來達到降低成本，在第二層粉刷時加入配置完成的色料以達到目的，這不但能減少成本還能減少其他裝潢材料所產生的環境污染成本。

五、突破傳統水泥染色實務瓶頸

- (一) 無法製作高彩度牆面
- (二) 不同顏色的牆面會有顏料滲色移形的缺點
- (三) 顏色不均勻導致無法實踐大面積高品質的工程外觀

此項研究，希望未來在亞洲地區一半以上的建築材料市場能夠認同，不管是外牆、室內裝潢、橋梁、公園與河岸的造景以及特殊的景觀人文藝術，加上易滿足於客製化的要求，可用在民宿、個人別墅以及博物館專題製作。在銷售方面上能以彩色水泥的方式進行估價計算，也可採用預鑄加預彩的施工方式，完成客戶所需求的個人專案，如果建築能多樣化，相信台灣的建築會更多彩多姿。

捌、參考資料

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- (十七) 尾上孝一，(圖解建築裝修材料及其施工方法)，東華書局

附錄一 (顏料無毒證明書)

Material Safety Data Sheet as per regulation (EC) 1907/2006
 Commercial Product Name: HEUCODUR Green G54
 Article No.: 1001259
 Revision date: 06.06.2013
 Version: 2.014
 Print Date: 06.06.2013

heubach
COMPETENCE IN COLOR

1. Identification of the substance/mixture and of the company/undertaking

Product Identifier
 Commercial Product Name: HEUCODUR Green G54
 HS/EC Name: cobalt titanate green spinel
 CAS no.: 68184-89-6
 EC-No.: 265-047-4
 REACH registration number: 01-211967333-43-0002

Relevant identified uses of the substance or mixture and uses advised against
Relevant identified uses
 Powder coating
 Pigment in articles
 Polycrystalline, heat-stabilizing
 Forming of pigments containing products
 Printing and other applications of pigments
Cautioning
 Treatment of articles by etching and coating
 Bulk applications, finishing, including hand mixing
Use and Toner
 Formulation of pigment products
 Pigment production including synthesis, filter press and grinding, spray drying, calcination and packaging

Details of the supplier of the safety data sheet
Company designation
 Heubach GmbH
 Heubach House 7
 D-10555 Langenfelde
 Telephone: +49(0)3320-52-5
 FAX: +49(0)3320-52-233
 Email: www.heubach.de
Responsible Document: Email: prodman.safety@heubach.com

Emergency telephone number
 Emergency telephone number:
 24-hour telephone service, Road
 Telephone: +49(0)531-19040
 (Germany/English)

2. Hazardous identification

Classification of the substance or mixture
 Classification according to GHS: Skin Sens. 1, H317 Carc. 1A; H350 STOT RE 2; H373
 GHS (EC) No.: 1222/2008
 Classification according to Directive 67/548/EEC / 1999/45/EEC: Carc. Cat. 1; R49, R59, R60, R63

Label elements
 hazard pictogram:




Material Safety Data Sheet as per regulation (EC) 1907/2006
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Physical and chemical properties
 Appearance: cobalt titanate green spinel
 H-statement(s): H317: May cause an allergic skin reaction.
 H350: May cause cancer by inhalation.
 H373: May cause damage to organs through prolonged or repeated exposure.
 P-statement(s): P201: Obtain special instructions before use.
 P202: Do not breathe dust/fume/gas/mist/vapors/spray.
 P203: Use personal protective equipment as required.
 P208+P232: If on skin: Wash with plenty of soap and water.
 P261+P511: If exposed or concerned: Get medical advice/attention.
 P501: Dispose of contents/container to a hazardous or special waste collection point. Always ensure with local / regional / national or international regulations.
 Further information: Restricted to professional users.

Other hazards
 Results of PBT and vPvB assessment: This substance does not meet the PBT/vPvB criteria of REACH Annex II.

3. Composition/information on ingredients

Chemical characterization: Substances
 Cobalt Titanate Green G54

Hazardous ingredients
 cobalt titanate green spinel

Ingredient	Classification (EC) No. E7, E48		Concentration by weight
	Classification (EC) 1272/2008	Classification (EC) 1272/2008	
cobalt titanate green spinel	Carc. Cat. 1; R49, R59, R60, R63	Carc. Cat. 1; R49, R59, R60, R63	5.0 - 10.0%
	Carc. 1A; H350 STOT RE 2; H373	Carc. 1A; H350 STOT RE 2; H373	

Other data: Full text of H-, P- and DSI-statements: see section 10.

4. First aid measures

Description of first aid measures
 General advice:
 If inhaled: Remove from off immediately all contaminated clothing. If breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing. If exposed or concerned: Get medical advice/attention.
 In case of skin contact: After contact with skin, wash immediately with plenty of water and soap.
 In case of eye contact: Rinse immediately and carefully and thoroughly with eye-bath or water. Keep eyelids open. Get medical advice/attention.

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COMPETENCE IN COLOR

5. Handling and storage

Precautions for safe handling
 Advice on safe handling: Carry out filling operations only at stations with exhaust ventilation facilities. Use suitable protective clothing. Wear respiratory protection. Avoid dust inhalation of dusts. Wear eye glasses with side protection according to EN 166. When using do not eat, drink or smoke.

Conditions for safe storage, including any incompatibilities
 Storage space and container requirements: Keep only in the original container. Store in a well-ventilated place. Keep container tightly closed.
 Advice on storage assembly: Do not allow food at the workplace.
 PNEC 510: Storage class 6.1 D.

Specific end uses
 Specific uses: No information available.

6. Exposure control/personal protection

Control parameters
 cobalt titanate green spinel
 (DMS)

Value	Target group	exposure route	Source
2.74 mg/m ³	Workers	DMS, long-term inhalative (systemic)	102
100 mg/m ³	Workers	DMS, acute inhalative (systemic)	102
0.05 mg/m ³	Workers	DMS, long-term inhalative (local)	102
0.01 mg/m ³	Workers	DMS, acute inhalative (local)	102
0.024 mg/m ³	Workers	DMS, long-term dermal (local)	102
20 mg/m ³	consumer	DMS, long-term inhalative (systemic)	102
0.02 mg/m ³	consumer	DMS, acute inhalative (systemic)	102
20 mg/m ³	consumer	DMS, long-term inhalative (local)	102
0.01 mg/m ³	consumer	DMS, acute inhalative (local)	102

EC - PNEC based
 PNEC

Value	Target group	Source
0.6 mg Ni/L	PNEC aquatic freshwater	102
0.6 mg Ni/L	PNEC aquatic marine water	102
0.05 mg Ni/L	PNEC sewage treatment plant (STP)	102
0.02 mg Ni/L	PNEC soil	102

EC - PNEC based

7. Environmental protection

Environmental precautions
 Do not allow to enter into surface water or drains. If the product contaminates lakes, rivers or sewages, inform competent authorities in accordance with local regulations.

Methods and material for containment and cleaning up
 Methods for cleaning up: Wet clean or vacuum up solids. Collect in closed and suitable containers for disposal. Clean contaminated objects and areas thoroughly observing environmental regulations. Avoid generation of dust.

Reference to other sections
 Reference to other sections: See protective measures under point 7 and 8. (Support: see section 13)



Exposure controls
 Respiratory protection: Respiratory protection with dust development. Particle filter with high removal capability for solid and liquid particles (e.g. M 145 or F9, type P3 or PFF3)
Hand protection
 Chemical proof protective gloves (EN 374 A.g. nitrile rubber (0.4mm), chloroprene rubber (0.5mm), polybutadiene (0.7mm), among others) due to large variety of types the manufacturer's instructions should be followed.
Eye protection
 Wear eye glasses with side protection according to EN 166.
Skincare and body protection
 Choose body protection device depending on operation and possible hazard, e.g. apron, protective boots, chemical protection suit (according to EN 14695 for sprays) or EN 60 13482 for dust.
General protective and hygiene measures
 In order to prevent contamination while handling, closed working clothes and working shoes should be worn, cover away from food, drink and animal feeding stuffs. Remove contaminated, saturated clothing immediately. Wash hands before breaks and after work. Separate storage of work clothes. When using as eat, drink or water.
Consumer exposure controls
 See chapter 7. No additional measures necessary.

9. Physical and chemical properties

Information on basic physical and chemical properties

Form	Powder
Colour	green
Odour	odorless
Odour threshold	not determined
pH	7,5 - 9
Melting point [°C]	not determined
Boiling point [°C]	not applicable
Boiling range [°C]	not applicable
Flash point [°C]	not applicable
Evaporation rate [kg/m ² /h]	not applicable
Flammability	not applicable
Explosion limit [vol-%]	not applicable
Risk of explosion	not explosive
Vapour pressure [hPa]	not applicable
Density [g/cm ³]	4,5
Relative density	not determined
Relative density of vapour / air (reference substance)	not applicable
Water solubility [g/l]	<0,1
Dissociation coefficient (reference substance) pKa	not applicable
Water solubility	not applicable



Viscosity, dynamic [kg/(m*s)]
 not applicable
Other information
 Other data: No information available.
10. Stability and reactivity
Reactivity
 Reactivity: No information available.
Chemical stability
 Chemical stability: Stable when applied the recommended regulations for storage and handling. Further information on correct storage, refer to chapter 7.
Possibility of hazardous reactions
 Hazardous reactions: No hazardous reactions when stored and handled according to instructions.
Conditions to avoid
 Conditions to avoid: No information available.
Incompatible materials
 Materials to avoid: No information available.
Hazardous decomposition products
 Hazardous decomposition products: No hazardous decomposition products if stored and handled as prescribed (indicated).

11. Toxicological information

Information on toxicological effects

Value	Test criterion	Test species	Test method
> 2000	LD50	Rat	OECD 401
Dermal toxicity [mg/kg]	not relevant		
Inhalative toxicity [mg/l]	not relevant		
Intram effect on skin			
Value	Test species	Exposure duration	Test method
Not an irritant	Rabbit	14 d	OECD 404
Intram effect on eye			
Value	Test species	Test method	
Not an irritant	Rabbit	OECD 405	
Intram effect on the respiratory tract	No information available		
Sensitization	May cause sensitization by skin contact.		
carcinogenic effect	May cause cancer by inhalation.		
Mutagenicity	No information available.		
Cluster effect	No information available.		



Specific target organ toxicity (single exposure) [mg/kg]
 Remarks: No information available.
Specific target organ toxicity (repeated exposure) [mg/kg]
 Remarks: Hazard: danger of serious damage to health by prolonged exposure through inhalation.
Aspiration hazard
 No information available.

12. Ecological information

Value	Test criterion	Test species	Exposure duration	Measuring method
> 3300	EC50	Limnion (Dan. sp. or other)	96h	EN 1841-2, part 2.4, BSF AC
Value	Test criterion	Test species	Exposure duration	Measuring method
> 330	EC50	Daphnia magna (5d water test)	48h	EC-Directive 92/331 Part A, Annex 9, Part C.2, BSF AC
Value	Test criterion	Test species	Exposure duration	Measuring method
> 330	EC50	1st reproduction (fish)	72h	OECD 201, BSF AC

Persistence and degradability
 Biodegradability: practically insoluble. The insoluble part can be processed mechanically in suitable sewage treatment plants.
Biocompatibility potential
 Biocompatibility: Due to the consistency along with the low water solubility of the product a biocompatibility is unlikely. Product contains heavy metals. Discharge into the environment must be avoided. Special pre-treatment is necessary. The product is not water based. The statement is derived from products of similar structure or composition.
Mobility in soil
 Mobility: No information available.
Results of PBT and vPvB assessment
 Results of PBT and vPvB assessment: This substance does not meet the PBT/vPvB criteria of REACH, Annex 13.
Other adverse effects
 Further information on ecotoxicity: This product is an inorganic substance. Due to its very low water solubility its health character the substance is not expected to be hazardous to sediment and terrestrial organisms.



13. Disposal considerations
Waste treatment methods
 Disposal considerations: Send to a hazardous waste incineration facility under observation of official regulations. Check for possible recycling.
 Recycled empty packaging: Contaminated packages must be completely emptied and can be re-used following proper cleaning. Packing which cannot be properly cleaned must be disposed of.

14. Transport information

Description of the goods	Land transport (CMR/ADR 800)	Marine transport (IMDG/Code of Practice)	Air transport (IATA/ICAO)
Remarks:	No dangerous good in sense of these transport regulations.	No dangerous good in sense of these transport regulations.	No dangerous good in sense of these transport regulations.

Special precautions for user
 Precautions: No information available.
Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code
 Transport in bulk according to Annex I of MARPOL 73/78 and the IBC Code: Not applicable.

15. Regulatory information

Chemical safety assessment
 Safety assessment: For this substance a chemical safety assessment has been carried out. The detailed Exposure Scenario are available under: http://www.heubach.com/chemicalsafety/ES_P250_Rev_3.pdf

16. Other information

R-phrases (applying to ingredients)
 R44: Other acute toxicity by skin contact.
 R49: Toxic danger of serious damage to health by prolonged exposure through inhalation.
 R50: May cause cancer by inhalation.
 R51: May cause cancer by ingestion.
 R52: May cause cancer by ingestion.
 R53: Causes damage to organisms through prolonged or repeated exposure.
H-statements (applying to ingredients)
 H311: May cause an allergic skin reaction.
 H330: May cause cancer by inhalation.
 H373: Causes damage to organisms through prolonged or repeated exposure.
Abbreviation and acronym
 AEC: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)
 AEA: Accord international concernant le transport des marchandises dangereuses par chemin de fer (Agreement Concerning the International Transport of Dangerous Goods by Rail)
 IMDG: International Maritime Code for Dangerous Goods
 IATA: International Air Transport Association



ATA-DGR: Dangerous Goods Regulations by the International Air Transport Association (IATA)
 IAO: International Civil Aviation Organization
 ICAO-TC: Technical Instructions by the International Civil Aviation Organization (ICAO)
 IT: Service Notice Publication
 ILO: International Labour Organization
 GHS: Globally Harmonized System of Classification and Labeling of Chemicals
 VCI: Verband der chemischen Industrie, Deutschland/German chemical industry association
 BUNDS: European Inventory of Existing Commercial Chemical Substances (EINECS)
 CLP: European List of Classified Chemical Substances
 CAS: Chemical Abstracts Service (Division of the American Chemical Society)
 GHS/CLP: Globally Harmonized System of Classification and Labeling of Chemicals
 WH: Verordnung über Arbeitsschutzmaßnahmen, Österreich (Ordinance on the safety of working conditions, Austria)
 VCE: Vöest-Alpine Chemicals (USA, LLC)
 ISO: International Organization for Standardization
 DNEL: Derived No-Effect Level (REACH)
 PNEC: Predicted No-Effect Concentration (REACH)
 L50: lethal concentration, 50 percent
 LD50: lethal dose, 50 percent

Classification for mixtures and used evaluation method according to regulation (EC) 1272/2008 (CLP)	Classification	evaluation
	Skin Sens. 1 (H317)	
	Carc. 2B (H350)	
	STOT RE 1 (H372)	

This information is provided in accordance with the current status of our knowledge and experience. The Safety Data Sheet describes products with a view to relevant safety requirements. This information does not constitute a warranty of properties, features or qualities.



1. Identification of the substance/mixture and of the company/manufacturing

Product identifier	HEUCODUR Blue 550
Commercial product name	HEUCODUR Blue 550
CAS no.	1245-16-0
EC No.	612-135-6
Relevant identified uses of the substance or mixture and uses advised against	Refrigerant, Blower, Coating
Details of the supplier of the safety data sheet	Company description: heubach GmbH, Heubachstrasse 7, D-34869 Langelsheim, Germany, T: +49 520 4272-1000, Fax: +49 520 4272-222, Email: info@www.heubach.de
Responsible Department	Head product safety/technical services
Emergency telephone number	GHS/CLP: +49 520 4272-1000, Emergency: +49 520 4272-1000 (Germany/Europe)

2. Hazard identification

Classification of the substance or mixture	This product is classified as not hazardous according to regulation (EC) (Annex II) No. 1272/2008
Classification according to Directive 67/548/EEC / 1989/609/EEC	This product is not classified as dangerous according to 67/548/EEC.
Label elements	The product does not have to be labeled according to Regulation (EC) No. 1272/2008 (CLP).
Other hazards	No risks worthy of mention.
Results of PBT and vPvB assessment	The substance does not meet the PBT/vPvB criteria of REACH, Annex VIII.

3. Composition, information on ingredients

Chemical name of mixture	rubulol blue base blue pigment
Chemical name of substance	CO: 19998, Blue 28, CAS No.: 1245-16-0

4. First aid measures

Description of first aid measures	Get medical attention if you feel unwell.
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Fire/fight	If breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing. Get medical advice/attention if you feel unwell.
In case of skin contact	Wash skin plenty of times with water. Remove immediately carefully and thoroughly with soap and water. If eye irritation occurs, get medical advice/attention.
In case of eye contact	Flush with water. Flush with water. If all signs of irritation persist, seek medical advice.
If swallowed	Do not induce vomiting. Do not give anything by mouth to someone who is unconscious. Do not give anyone who has swallowed anything to eat or drink. Do not give anyone who has swallowed anything to drink.
Indication of any immediate medical attention and special treatment needed	That is responsible.

5. Handling and storage

Exhausting media	Exhausting media: Water, soap, pH. In case of eye and face contact: Water, soap, pH, avoid contact with face.
Exhausting media with special instructions for safety reasons	Carboxamide (CO2)
Special hazards arising from the substance or mixture	The product is not classified as a PBT/vPvB substance. For spraying measures to the surface, use suitable protective equipment. Avoid breathing dust/fume/gas/aerosol/spray.
Advice for firefighters	In case of fire: Wear self-contained breathing apparatus.

6. Occupational exposure measures

Personal protection, protective equipment and arrangements	Wear personal protective equipment, see chapter 8.
Personal protection	Wear breathing apparatus if exposed to vapors/aerosols.
Environmental protection	Do not allow to enter into surface water or drains. If the product contaminates lakes, rivers or streams, inform competent authorities in accordance with local regulations.
Methods and material for containment and cleaning up	Use clean or soapy up solids. Collect in closed and suitable containers for disposal. Clean contaminated objects and areas thoroughly observing environmental regulations.
References to other sections	See protective measures under point 7 and 8. Disposal see section 13.



7. Handling and storage

Precautions for safe handling	Wear suitable protective clothing. If the formation of dust is beyond the occupational exposure limit values, approved and suitable respiratory protection must be used. Wear eye glasses with side protection according to EN 166. When using do not eat or drink.
Conditions for safe storage, including any incompatibilities	Store in a well-ventilated place. Keep container tightly closed. Storage class: 13.
Specific end uses	No information available.

8. Exposure controls/personal protection

Control parameters	Respiratory protection: If the formation of dust is beyond the occupational exposure limit values, approved and suitable respiratory protection must be used.
Respiratory protection	Hand protection: By short-term hand contact. Hand protection is not required. In case of prolonged or frequently repeated skin contact: Wear suitable gloves.
Hand protection	Wear suitable gloves: NBR, polyurethane, leather. See information supplied by the manufacturer.
Eye protection	Wear eye glasses with side protection according to EN 166.
Personal protective and hygiene measures	Provide adequate ventilation as well as local extraction at critical locations.
Customer exposure controls	See chapter 7. No additional measures necessary.

9. Physical and chemical properties

Information on basic physical and chemical properties	Physical state: solid
Form	Powder
Colour	blue
Odour	odorless
Relative density	not determined
pH	7 - 9
Melting point (°C)	not determined
Boiling point (°C)	not applicable
Boiling range (°C)	not applicable

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 Issue date: 11.02.2013



Flash point [°C]	not applicable
Explosive limit [kg/m³]	not applicable
Flammability	not applicable
Explosion limits [Vol-%]	not determined
Risk of explosion	not explosive
Vapour pressure [kPa]	not determined
Density [g/cm³]	4.3
Relative density	not determined
Relative density of a vapour / air mixture (assumed)	not determined
Water solubility [g/l]	<0.1
Partition coefficient n-octanol/water (log P _{OW})	not applicable
Autoflammability	not applicable
Viscosity, dynamic [kPa·m/s]	not applicable
Other information	No information available.

10. Stability and reactivity

Reactivity	No information available.
Stability	No information available.
Chemical stability	Stable when applying the recommended regulations for storage and handling, further information on correct storage refer to chapter 7.
Chemical stability	Stable when applying the recommended regulations for storage and handling, further information on correct storage refer to chapter 7.
Possibility of hazardous reactions	No hazardous reactions when stored and handled according to instructions.
Hazardous reactions	No hazardous reactions when stored and handled according to instructions.
Conditions to avoid	No information available.
Conditions to avoid	No information available.
Incompatible materials	No information available.
Materials to avoid	No information available.
Hazardous decomposition products	No hazardous decomposition products if stored and handled as prescribed/instructed.
Hazardous decomposition products	No hazardous decomposition products if stored and handled as prescribed/instructed.

11. Toxicological information

Information on toxicological effects	Not as irritant.
Irritant effect on eyes	Not as irritant.
Irritant effect on the respiratory tract	Not as irritant.

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12. Regulatory information

Chemical safety assessment	For this substance a chemical safety assessment has not been carried out.
Safety assessment	For this substance a chemical safety assessment has not been carried out.

13. Other information

Abbreviations and acronyms	ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road) IMD: Règlement international concernant le transport des marchandises dangereuses par chemin de fer (Regulations Concerning the International Transport of Dangerous Goods by Rail) IMDG: International Maritime Code for Dangerous Goods IATA: International Air Transport Association IATA-DGR: Dangerous Goods Regulations by the "International Air Transport Association" (IATA) ICAO: International Civil Aviation Organization ICAO-TI: Technical Instructions by the International Civil Aviation Organization ITCARD: ITCARD P: Stoffe, Gefahrstoffe P: Gefahrstoffe P: Gefahrstoffe GHS: Globally Harmonized System of Classification and Labeling of Chemicals VCI: Verband der chemischen Industrie, Deutscher Gewerkschaftsbund (German Chemical Industry Association) EINECS: European Inventory of Existing Commercial Chemical Substances ELINCS: European List of Notified Chemical Substances CAS: Chemical Abstracts Service (division of the American Chemical Society) GHS/GH: Gefahrstoffverordnung (Ordinance on Hazardous Substances, Germany) MFR: Verordnung über brennbare Flüssigkeiten, Österreich (Ordinance on the storage of combustible liquids, Austria) VCI: Verband der chemischen Industrie, Deutscher Gewerkschaftsbund (German Chemical Industry Association) ILO: International Organization for Standardization OEL: Occupational Exposure Limit (OEL) PNEC: Predicted No-Effect Concentration (PNEC) LC50: Lethal concentration, 50 percent LD50: Lethal dose, 50 percent
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This information is provided in accordance with the current status of our knowledge and experience. The Safety Data Sheet describes products with a view to relevant safety requirements. This information does not constitute a warranty of properties, features or quality.

Material Safety Data Sheet as per regulation (EC) 1907/2006
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Additional information	When used and handled according to specifications, the product does not have any harmful effects to our experience and the information provided to us.
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14. Ecological information

Toxicity	No information available.
Aquatic toxicity [mg/l]	No information available.
Persistence and degradability	not applicable
Biodegradability	not applicable
Biocumulative potential	This product is an inorganic substance. Due to its very low water solubility and its inert character the substance is not expected to be bioavailable to sediment and terrestrial organisms.
Biocumulative potential	This product is an inorganic substance. Due to its very low water solubility and its inert character the substance is not expected to be bioavailable to sediment and terrestrial organisms.
Mobility in soil	not relevant
Mobility	not relevant

Results of PBT and vPvB assessment: This substance does not meet the PBT/vPvB criteria of REACH, Annex XI.

15. Disposal considerations

Waste treatment method	Send to a hazardous waste incineration facility under observation of official regulations. Check for possible recycling.
Disposal considerations	Send to a hazardous waste incineration facility under observation of official regulations. Check for possible recycling.
Waste code	05 01 17 waste from other than those mentioned in 05 01 11
Unlabeled waste packaging	Containerized packages must be completely emptied and can be re-used following proper cleaning. Packing which cannot be properly cleaned must be disposed of.

16. Transport information

Description of the goods proper shipping name	Land transport (ADR, RID)	Marine transport (IMDG, Code of Practice)	Air transport (IATA, DGR)
	Not dangerous goods	Not dangerous goods	Not dangerous goods

Special precautions for user: No special measures are necessary.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code: Not applicable.
 Transport in bulk according to A2 of MARPOL 73/78 and the IBC Code: Not applicable.

【評語】 091201

研究團隊以無機色料添加於水泥砂漿與混凝土，展示取代傳統水泥漆或磁磚施作之可行性，並進行力學實驗以驗證強度不受色料影響，研究動機充分且明確。改進建議如下：

1. 彩色水泥砂漿或混凝土在業界或國內外應已有實例應用，文獻蒐集上應加強此部分資料之蒐集與整理，以釐清不同配方或組成之優缺點。
2. 實驗設計同時比對採用一般砂、石英砂與金鋼砂對水泥砂漿試體與混凝土試體在標準抗壓與抗拉試驗之強度變化，在實驗設計上應針對水泥砂漿與混凝土在實際工程應用而有不同試驗設計，如增加水泥砂漿流度試驗。所引用之 ASTM 或 CNS 試驗規範編號宜再確認。
3. 所研發之彩色水泥砂漿或混凝土在未來實際施工方法之探討仍需考量，如清水模於柱面或牆面如何施作。